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20th November, 1957

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LERWICK OBSERVATORY
SHETLAND

The relation between anomalies of surface air temperature and of 1000-500 mb thickness over the Atlantic sector of the Northern Hemisphere

by

C. A. S. Lowndes

(Meteorological Office)

AIR MINISTRY

METEOROLOGICAL RESEARCH COMMITTEE

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The relation between anomalies of surface air temperature and of 1000-500 mb thickness over the Atlantic sector of the Northern Hemisphere.

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C.A.S. Lowndes (Meteorological Office)

Summary

The preparation is described of two series of charts covering the Atlantic sector of the Northern Hemisphere, one giving the monthly mean surface temperature anomaly and the other the monthly mean 1000-500 mb thickness anomaly for each month of the year 1956.

From a comparison of the charts month by month, it is evident that the main features of the thickness anomaly patterns are reflected in the surface temperature anomaly patterns. The importance of this relationship to a long-range forecasting method is discussed. In the Appendix, charts are produced to show how the temperature anomaly patterns are affected by the choice of the period used to obtain the normal from which the anomalies are measured.

1. Introduction

Since May 1955, the work of the Forecasting Research Division has included the construction of 5-day mean temperature anomaly charts covering the Atlantic half of the Northern Hemisphere. The preparation of these charts is described by Craddock and Lowndes (1956). Many of the temperature anomaly patterns are large, slow-moving and long lived, suggesting a relation with the character of the general circulation.

From August 1955, charts of monthly mean temperature anomaly were derived from the 5-day charts and were used to forecast the general character of the weather in South-east England during the following month by choosing an analogue for the anomaly chart from past years, an experiment which met with some success.

The present work was undertaken to clarify the relationship between the temperature anomaly patterns and the general circulation. The 1000-500 mb thickness was chosen for comparison with the mean surface temperature because it was regarded as characterising the upper air circulation.

2. The preparation of monthly mean thickness anomaly charts

The work of the Forecasting Research Division has included since 1949 the construction of monthly mean thickness charts for the whole Northern Hemisphere based on 0300Z synoptic charts. From these data, 5-year mean charts have been prepared for the Northern Hemisphere based on the period 1949-53 for the months June to December and on 1950-54 for January to May.

/The

The thickness anomaly charts were obtained by graphical subtraction from each monthly mean thickness chart of the appropriate 5-year mean chart. Isopleths are drawn at intervals of 20 metres, with the zero isopleths shown as pecked lines. Assuming a standard I.C.A.O. atmosphere, a thickness anomaly of 20 metres corresponds to an anomaly of 0.99°C in the mean temperature of the 1000-500 mb layer. The isopleths of thickness anomaly thus closely correspond to isopleths of mean upper air temperature anomaly drawn at 1°C intervals. On the same assumption, the maximum values at the centres of the patterns are shown to the nearest whole degree celsius. This facilitates comparison with the surface temperature anomaly charts.

3. The preparation of monthly mean surface temperature anomaly charts

The 5-day charts from which the monthly mean temperature anomaly charts were derived were based on long period means mostly obtained from data for the period 1921-1940. To make them comparable with the thickness anomaly charts it was necessary to refer the values to a 5-year mean based on the period 1949-53 (1950-54). The 5-year mean was evaluated for the network of stations shown on the key chart (see Appendix). The network was restricted to an area westward of 30°E because monthly temperature data for Eastern Europe were not available. The difference between the 20-year and the 5-year mean* was obtained for each station and was added to the value of the monthly mean temperature anomaly, thus referring it to the 5-year mean. Revised charts of monthly mean temperature anomaly were prepared in this way for each month of 1956. Isopleths are drawn at 1°C intervals with the zero isopleths shown as pecked lines. The maximum value at the centre of each area is shown to the nearest whole degree.

4. A comparison of the surface temperature and thickness anomaly patterns for each month of 1956

January (Fig. 1A, 1B)

The patterns in January show a marked similarity. The two main features, the warm area centred over Hudson Bay and the cold area near Iceland, are very similar in position, extent and intensity. An exception occurs over the Atlantic where the extension southwards of the cold thickness anomaly is not reflected to the same extent at the surface.

/February

Note. *Charts of the differences between the long period means for each month are reproduced as an appendix to this paper. Large differences occur over America and Greenland, in particular during the months January to March. A value of about 7°C occurs in January near the west coast of America. For all stations, one mean was based on a 5-year period; for the months June to December on 1949-1953 and for January to May on 1950-1954. The other mean was for the majority of stations based on the 20-year period, 1921-1940. For a few stations in Canada, it was based on a 30-year period, 1921-1950. These stations are indicated on the key chart by the figure 30. For a number of stations, particularly over Northern Canada and Greenland, it was based on various numbers of years within the period 1921-1940. The number of years used is shown on the key chart next to the name of the station.

Isopleths are drawn at 1°C intervals with the zero isopleths shown as pecked lines. The maximum value at the centre of each area is shown to the nearest whole degree.

February (Fig. 2A, 2B)

The patterns are very similar in February with the maximum values at the centre of each area comparable in magnitude. The main differences occur over Eastern America where the warm area extends further southward and the Newfoundland cold area further northward on the surface chart.

March (Fig. 3A, 3B)

The main feature of the March chart is a cold area which is centred over Eastern Canada and is of the same intensity on both charts. The Rockies warm area, though of similar intensity on both charts, extends further northward and eastward on the surface chart. The main difference is associated with the warm area near Iceland which extends further southward in the region of the British Isles on the surface chart. This difference seems to have been associated with surface warmth in persistent south-easterly advection with cooler air aloft.

April (Fig. 4A, 4B)

The patterns in April are much weaker and although the general distribution and intensities are similar, the extent and shape of the areas are much less comparable than in the earlier months. The main differences are associated with the warm area near Greenland which is centred further west and extends further west on the surface chart. The cold area over Eastern Greenland on the surface chart was associated with persistent northerly advection in the lower layers on the east side of a warm anticyclone over Greenland.

May (Fig. 5A, 5B)

The well-defined pattern over America in May is very similar on both charts, with the cold area extending somewhat further westward towards the Rockies on the thickness chart. The extension of the cold area to the east of Iceland on the thickness chart is not reflected at the surface where a warm area is situated over the Norwegian Sea. The patterns over Europe are very weak and show little similarity.

June (Fig. 6A, 6B)

The thickness chart for June shows an extensive cold area stretching from Greenland across the Atlantic to Western Europe and a warm area over central America. These features are generally similar on the surface chart but differ considerably in detail. The extension of the warm area northward across Canada on the thickness chart is not reflected in the surface chart where a weak cold area is centred over Hudson Bay.

A further difference occurs to the east of Greenland where the thickness chart shows an extension of the cold area but the surface chart a weak warm area.

July (Fig. 7A, 7B)

In July, the well-defined patterns over America, a weak cold area near Iceland and a warm area over Scandinavia are similar on both charts. The weak warm area to the North-west of the Azores does not appear on the thickness chart. The most remarkable difference occurs over South-West Europe where a cold area centred over Northern Italy on the surface chart does not appear on the thickness chart.

August (Fig. 8A, 8B)

The patterns in August although mainly weak, show a marked similarity of position and intensity on both charts.

/September

September (Fig. 9A, 9B)

The patterns over America in September are similar on both charts and the mainly rather weak patterns elsewhere are similarly positioned. The main difference occurs over Greenland where the cold area on the thickness chart is more intense and centred further north than on the surface chart.

October (Fig. 10A, 10B)

The main feature of the October charts is a warm area over America centred to the south of Hudson Bay on the thickness chart but further south-west on the surface chart. The extension of the warm area across the Atlantic to Spain and the cold area over Western Europe are similar on both charts. The main differences are associated with the area west of Hudson Bay where a cold area on the thickness chart does not appear on the surface chart, and to the west of Greenland where the cold area extends much further south on the surface chart.

November (Fig. 11A, 11B)

The patterns in November are very similar with the exception of the area south of Hudson Bay where a weak warm area at the surface does not appear on the thickness chart.

December (Fig. 12A, 12B)

The large patterns in December are very similar in position and extent on both charts. The charts differ from those of all the other months in that the maximum values at the centre of all the areas are much larger on the surface chart.

5. Discussion

The patterns, especially the more intense ones, are in the main similar on both charts throughout the year. Assuming a standard I.C.A.O. atmosphere, the maximum values of temperature anomaly are of the same order of magnitude on both charts.

Thickness patterns with a maximum anomaly of 2°C or more are, with three exceptions, reflected in a similar manner on the surface chart. In most cases a similar geographical area is covered but there is often some difference in the position of the centre, especially with the less intense patterns.

The exceptions occur (1) in April over Greenland, (2) in June to the north-west of Hudson Bay and (3) in September over Northern Greenland, suggesting that in these regions, and probably in other localities with peculiar surface characteristics, the surface pattern may not, under certain conditions, reflect the thickness pattern.

Surface patterns with a maximum anomaly of 3°C or more are, with two exceptions, reflections of similar patterns on the thickness chart. The exceptions occur (1) in April near Greenland and (2) in July over the Mediterranean area.

The close association between the two sets of patterns suggests that it is in general justifiable to use the more intense surface patterns as indicators of the character of the horizontal temperature field in the troposphere.

As mentioned already, Craddock and Lowndes (1956) have shown that the field of temperature anomaly at the earth's surface may show very persistent features lasting up to a month or two. The present work makes it seem very probable that the same persistent features would be found by examination of any other measure of the horizontal temperature field in the troposphere.

/If

If these features are indicators which can be used as a basis for successful forecasting it does not matter much whether they are identified by means of the surface temperature patterns, which are available in detail over a long period of years, or by means of patterns of the 1000-500 mb thickness which are available for only about a decade. However, the clear relation between the surface temperature anomalies and the upper air circulation may assist us in interpreting their cause.

Reference

Craddock, J.M. and Lowndes, C.A.S. 1956. A synoptic study of anomalies of surface air temperature over the Atlantic half of the Northern Hemisphere.

FIG 1A TEMPERATURE ANOMALY °C
JANUARY 1956

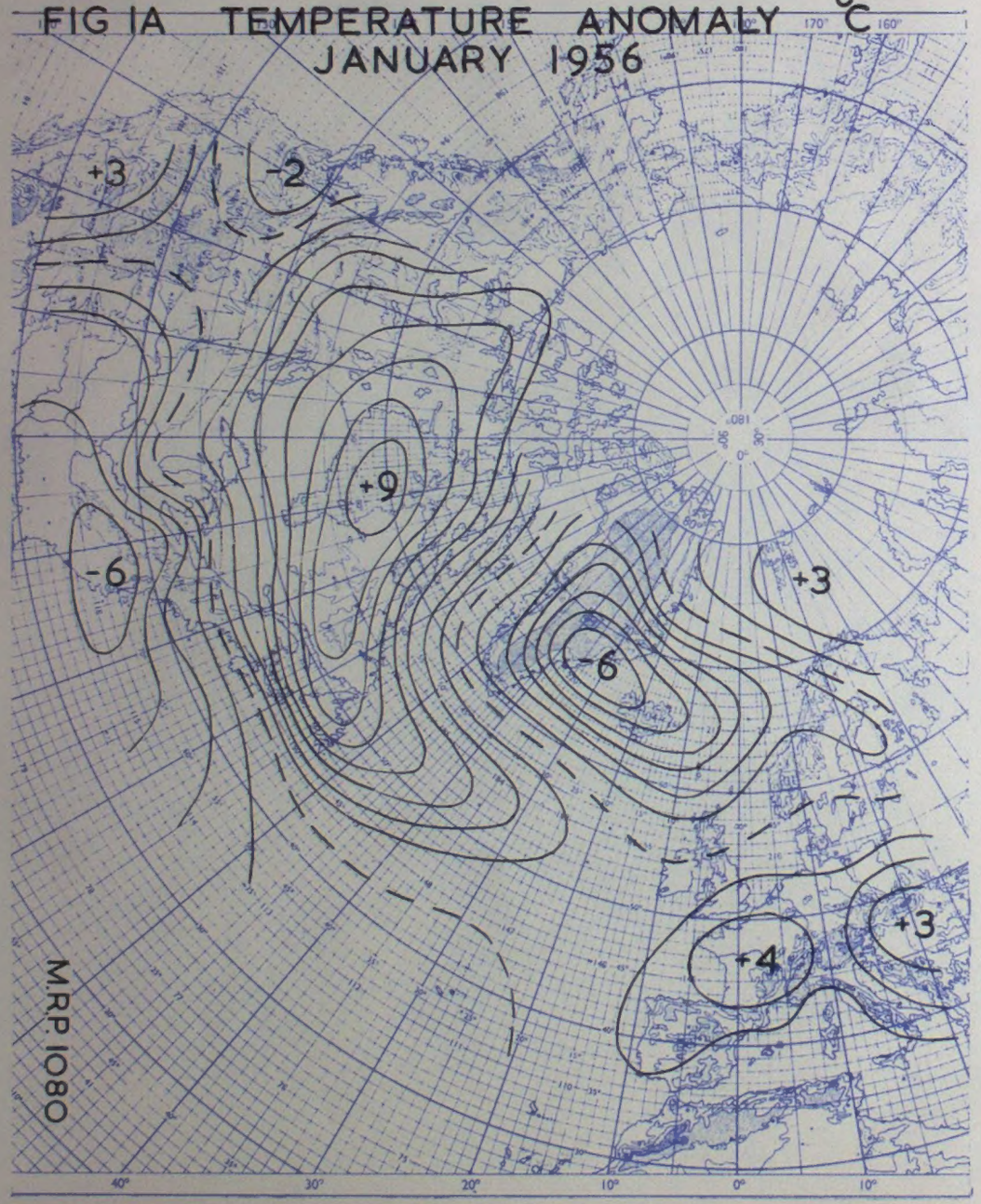
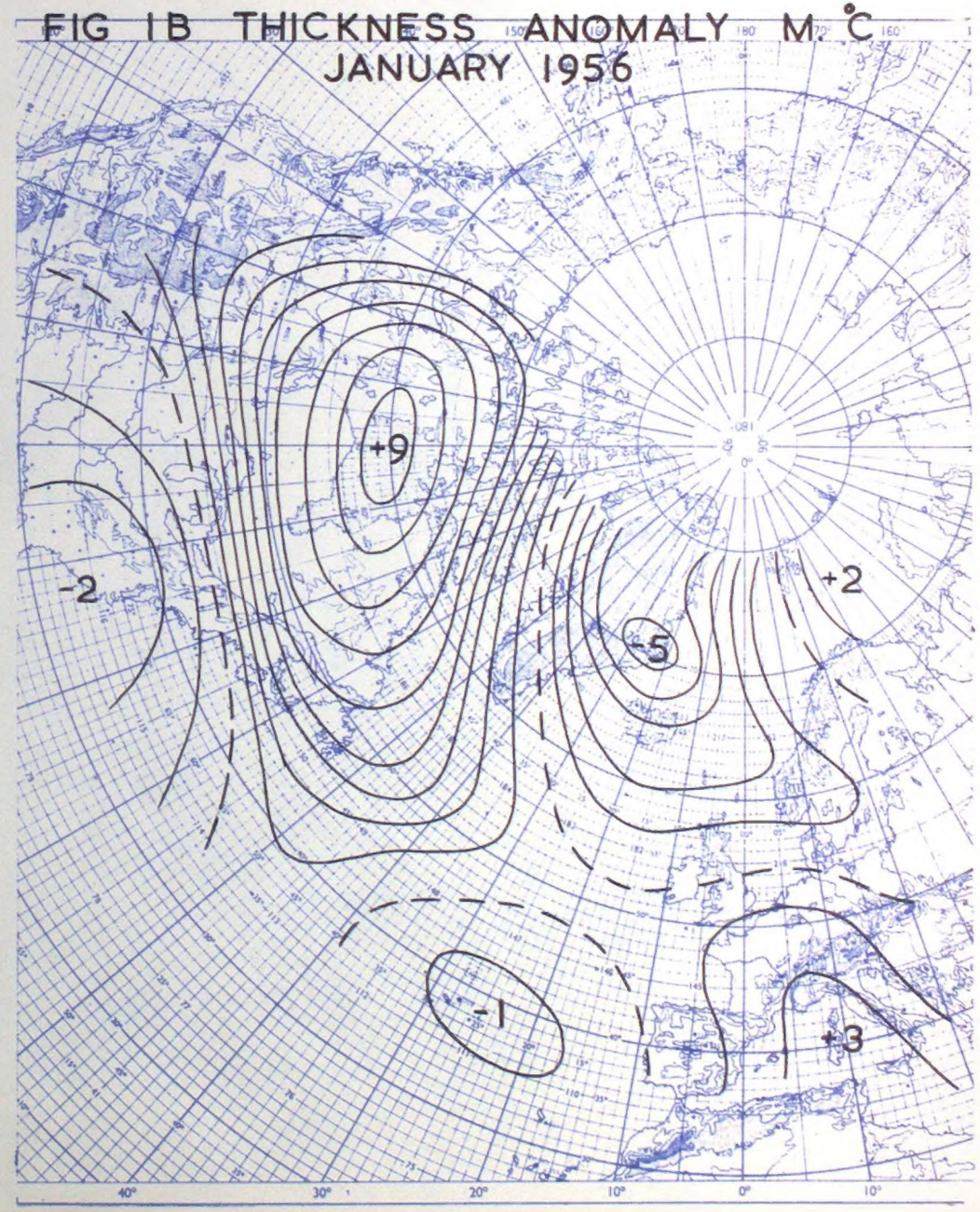


FIG 1B THICKNESS ANOMALY M. °C
JANUARY 1956



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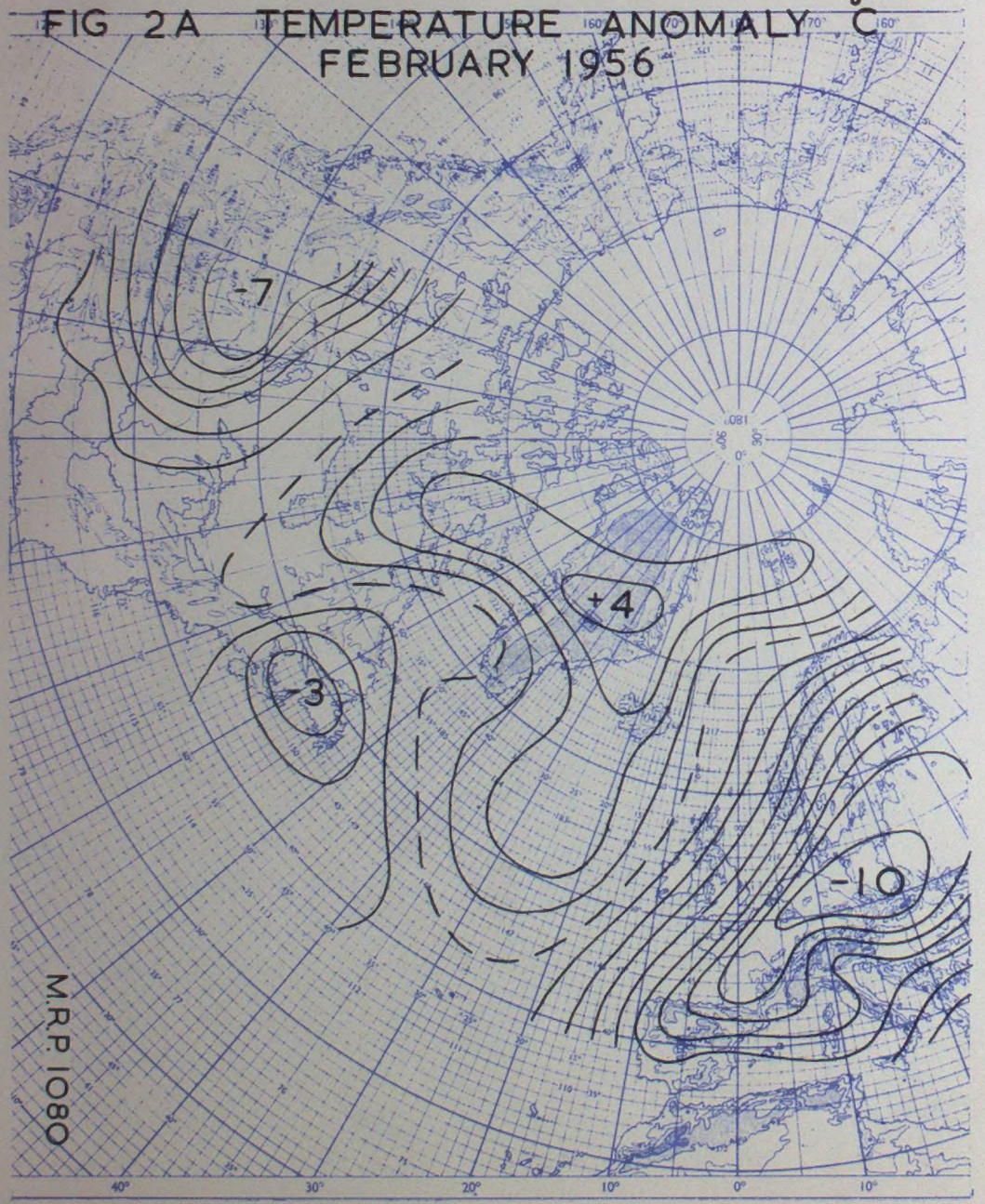
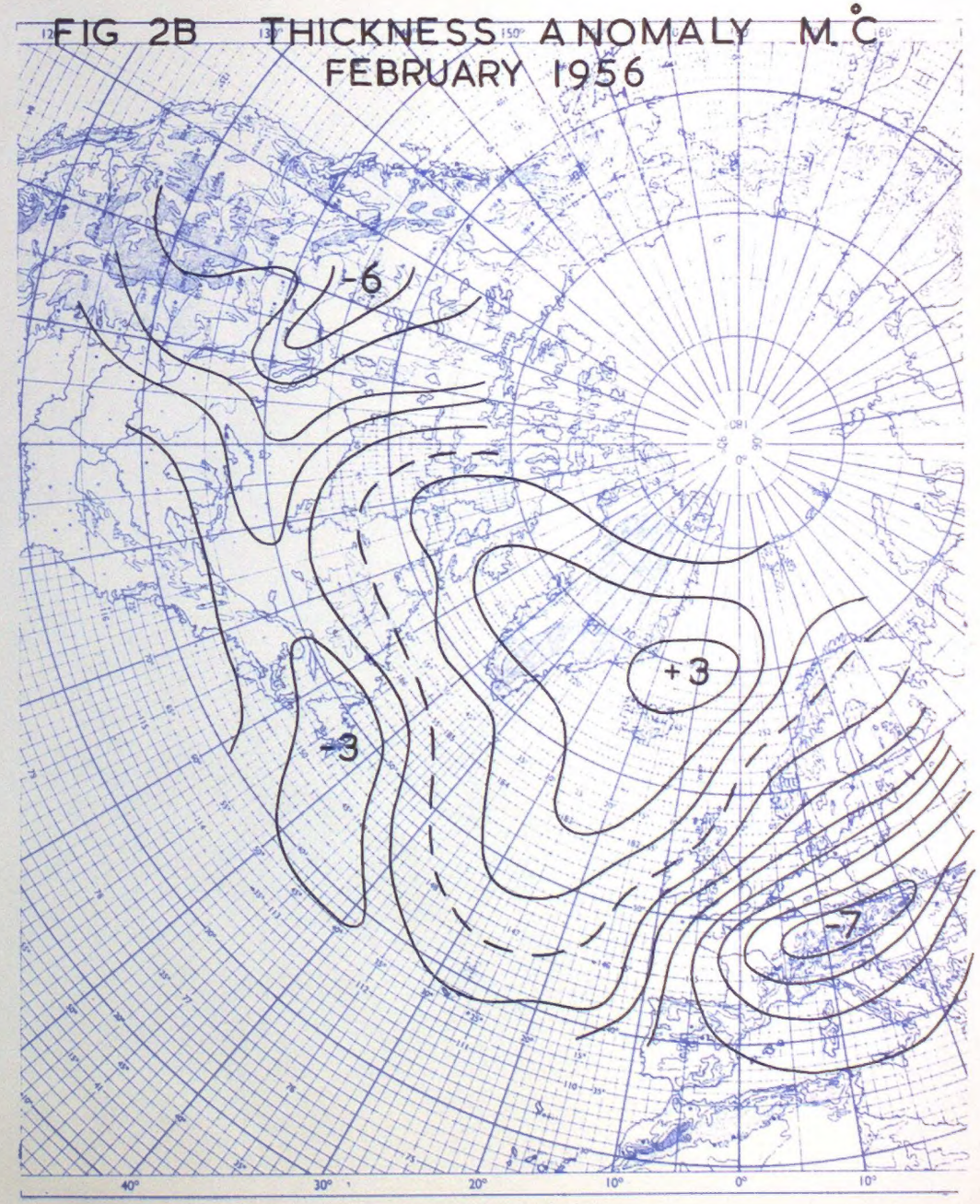


FIG 2B THICKNESS ANOMALY M. °C
FEBRUARY 1956



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MARCH 1956

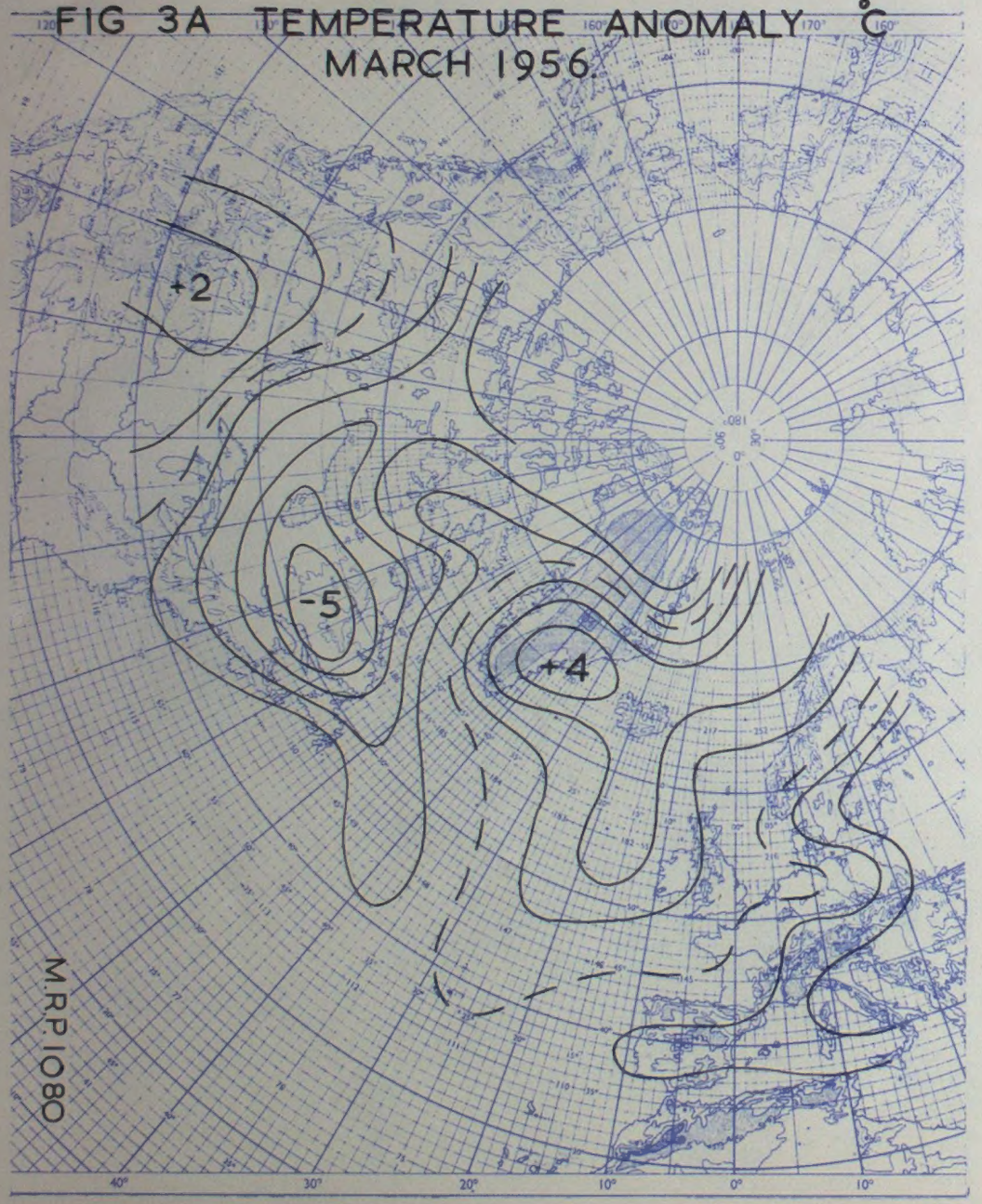

FIG 3B THICKNESS ANOMALY M. °C
MARCH 1956

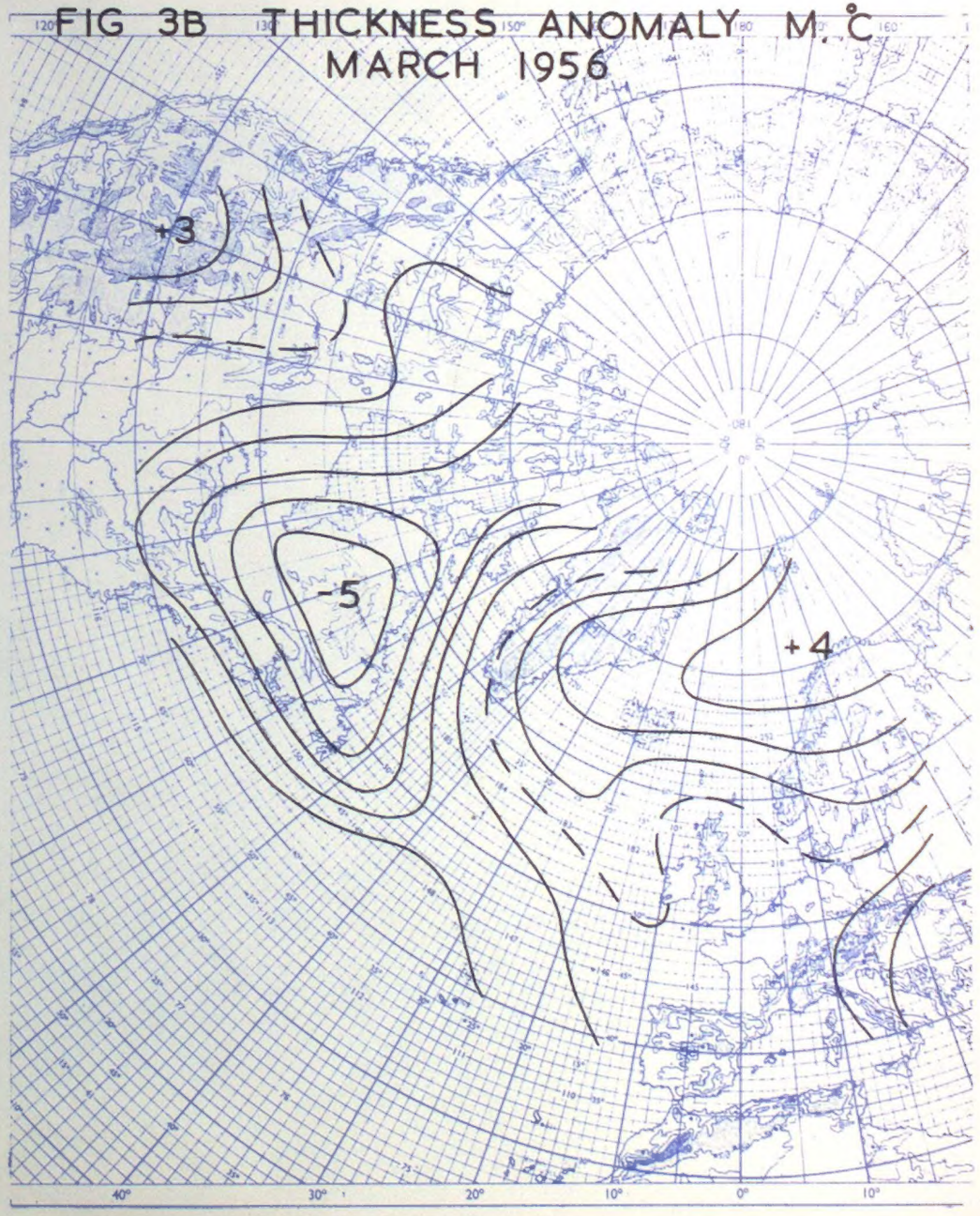

FIG 4A TEMPERATURE ANOMALY °C
APRIL 1956

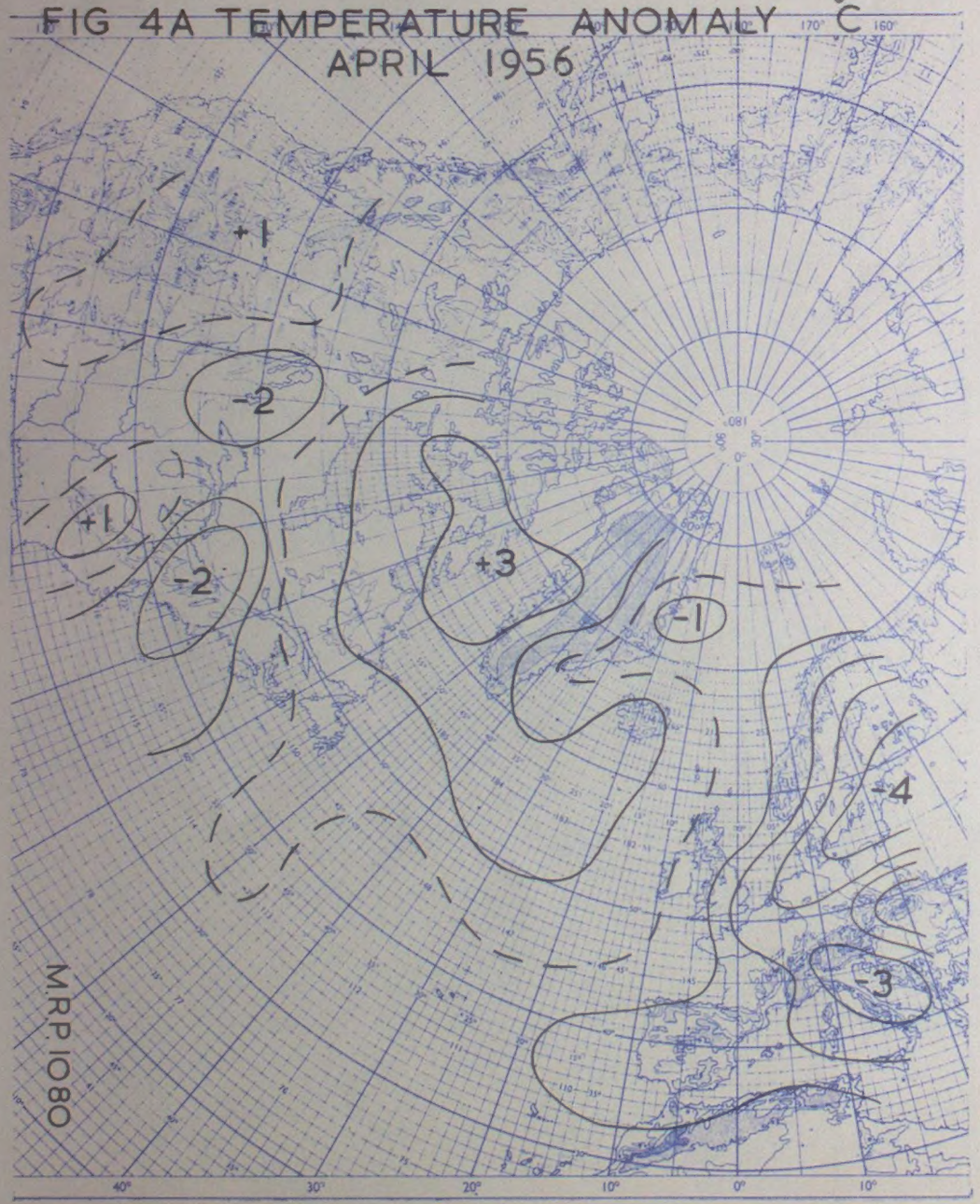

FIG 4B THICKNESS ANOMALY M. °C
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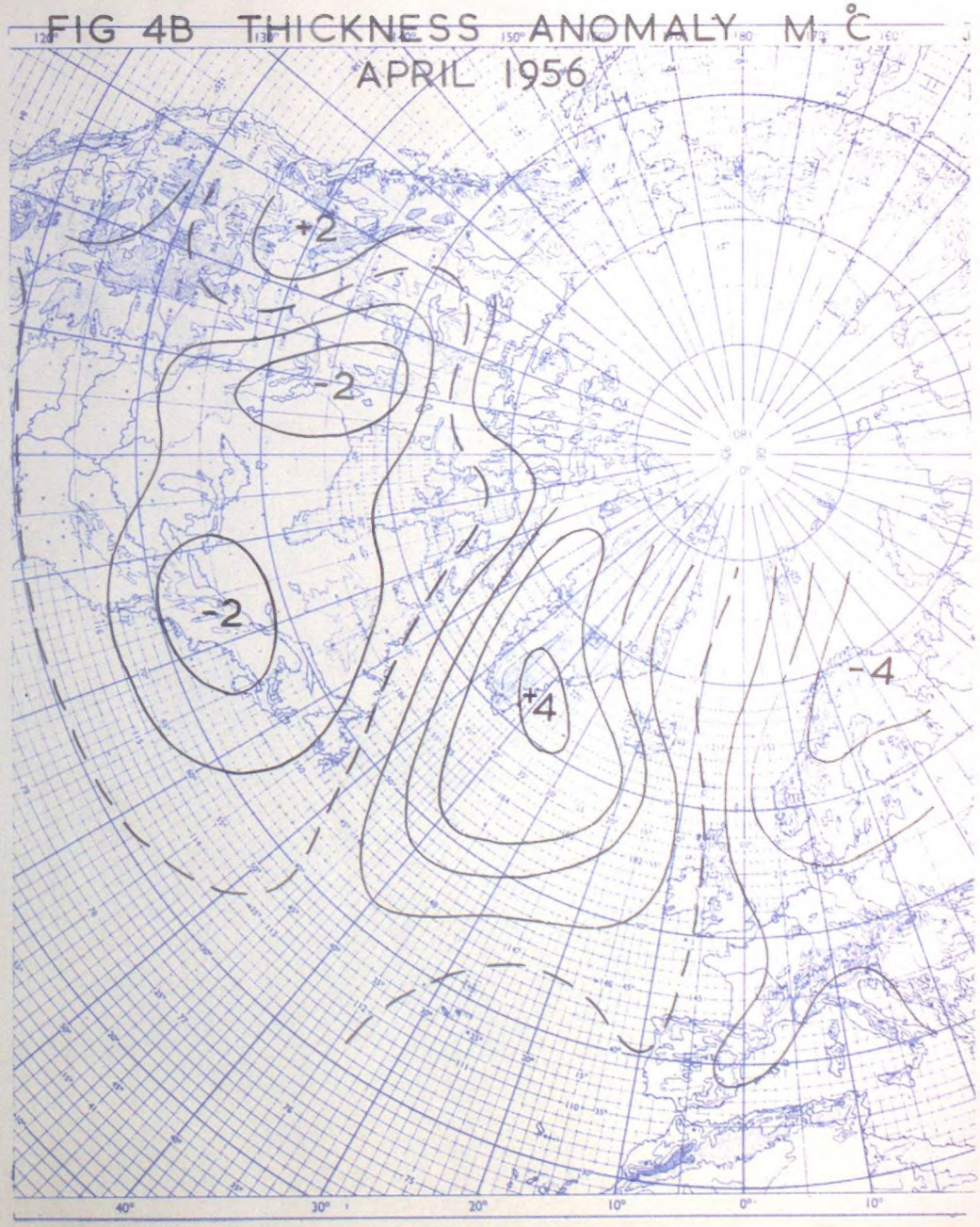

FIG 5A TEMPERATURE ANOMALY °C
MAY 1956

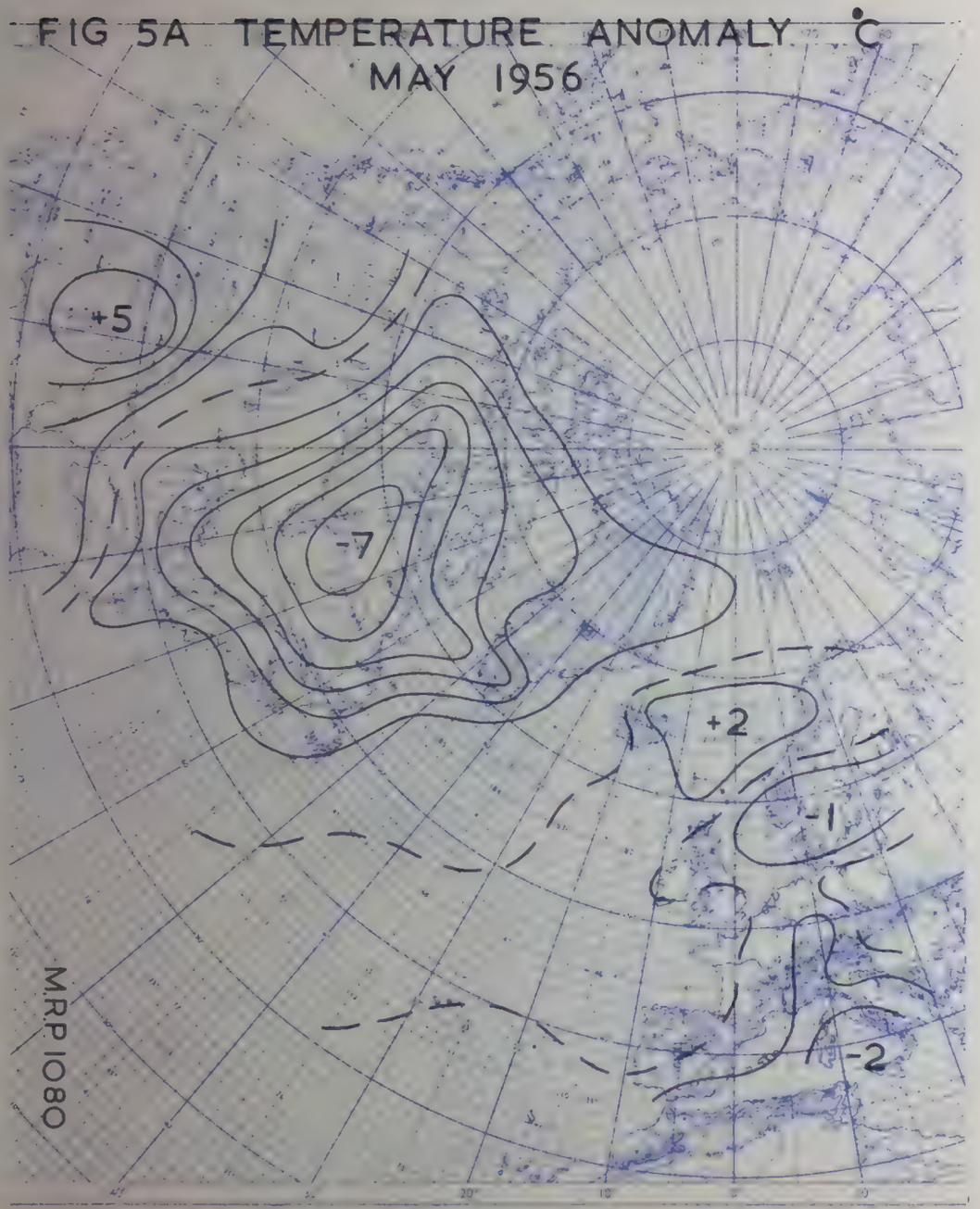

FIG 5B THICKNESS ANOMALY M. °C
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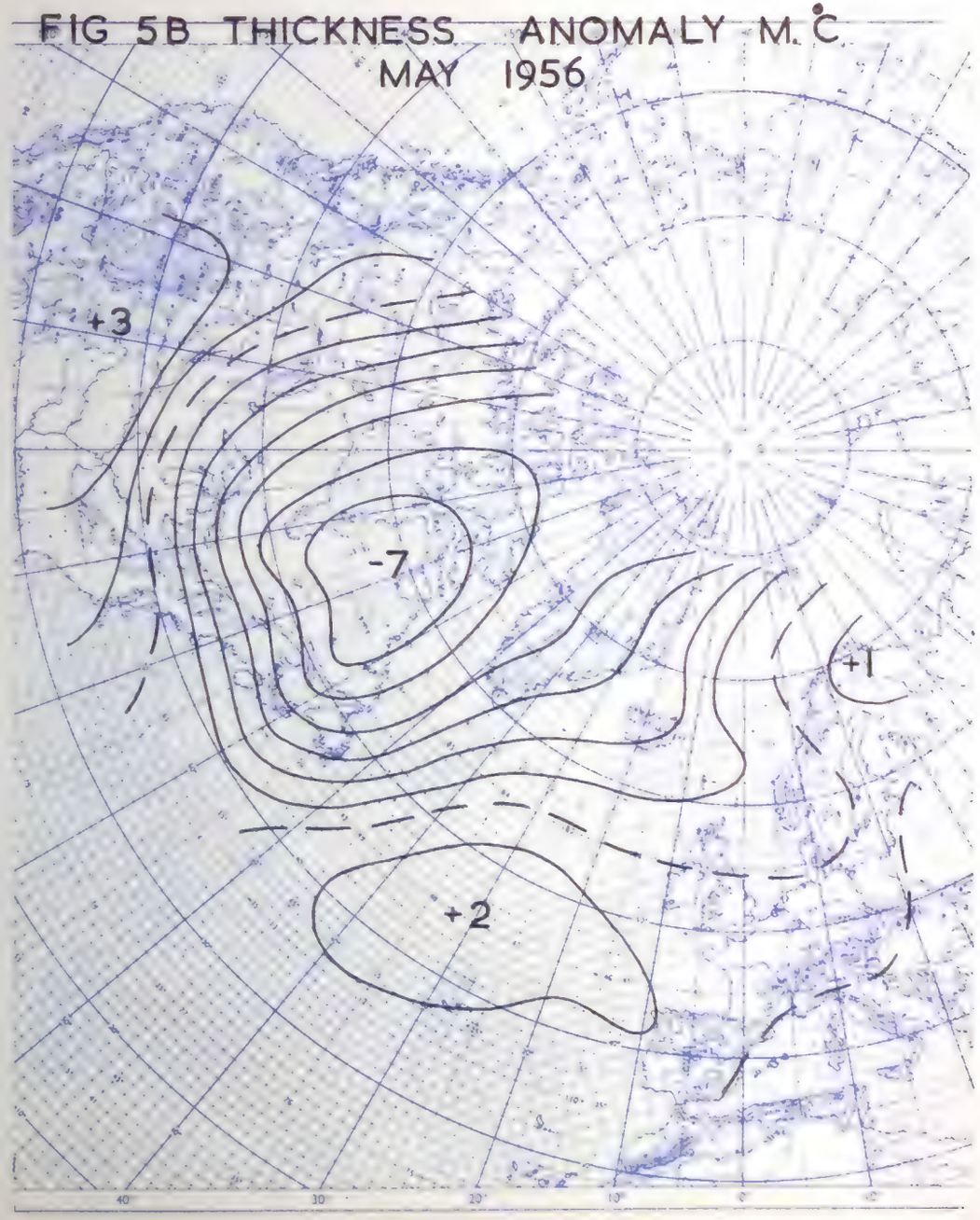

FIG 6A TEMPERATURE ANOMALY °C
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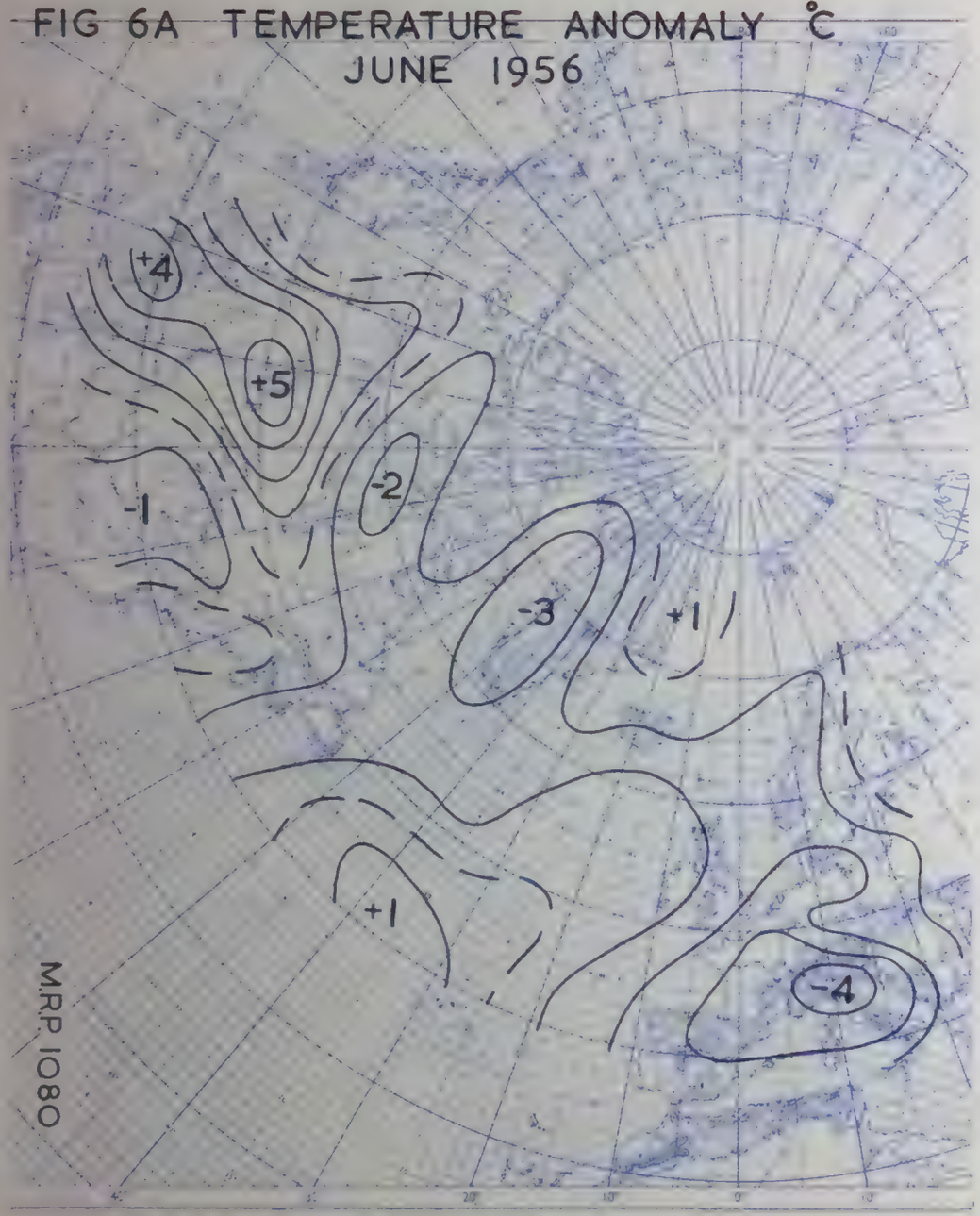

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FIG 6B THICKNESS ANOMALY M °C
JUNE 1956

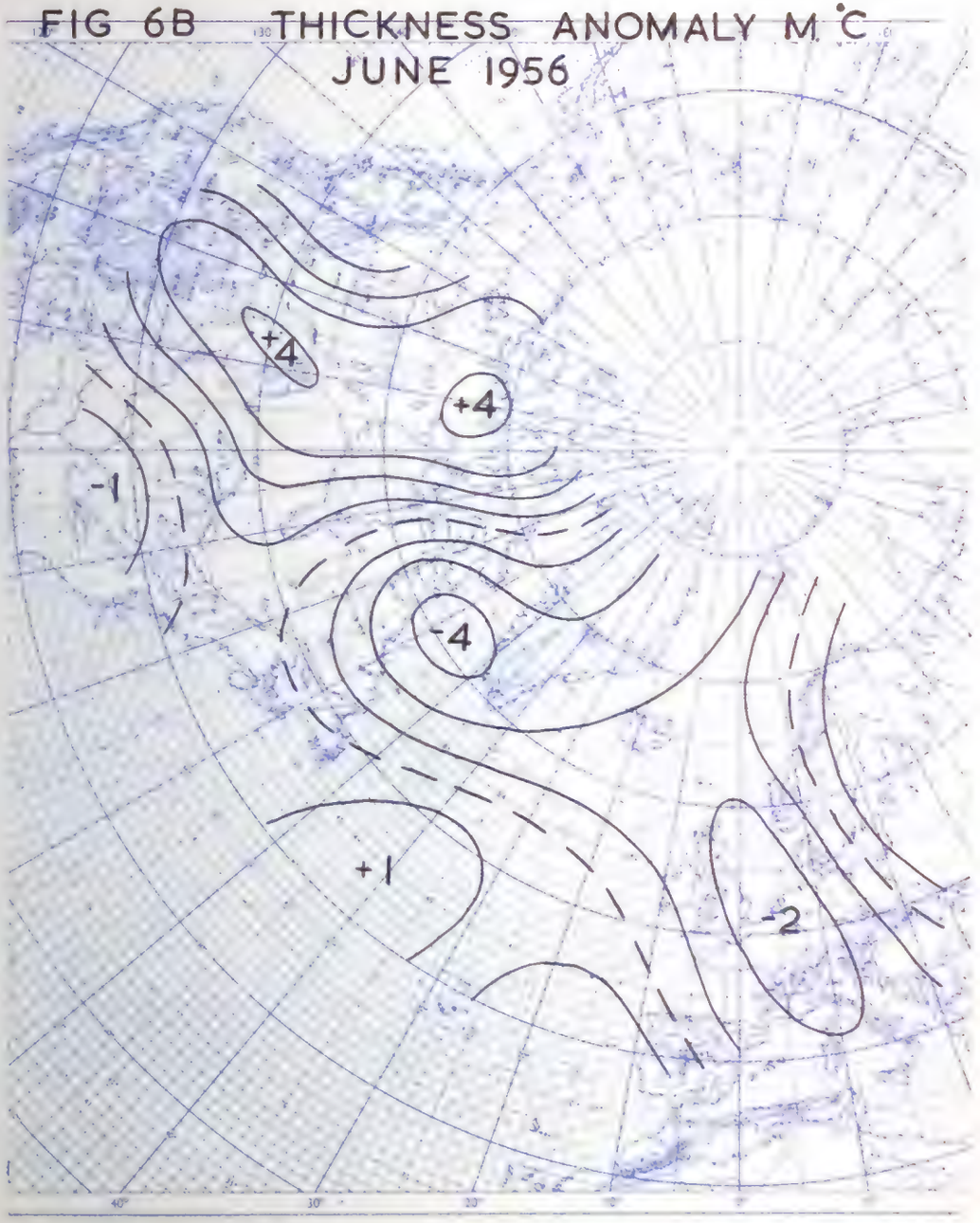

FIG 7A TEMPERATURE ANOMALY °C
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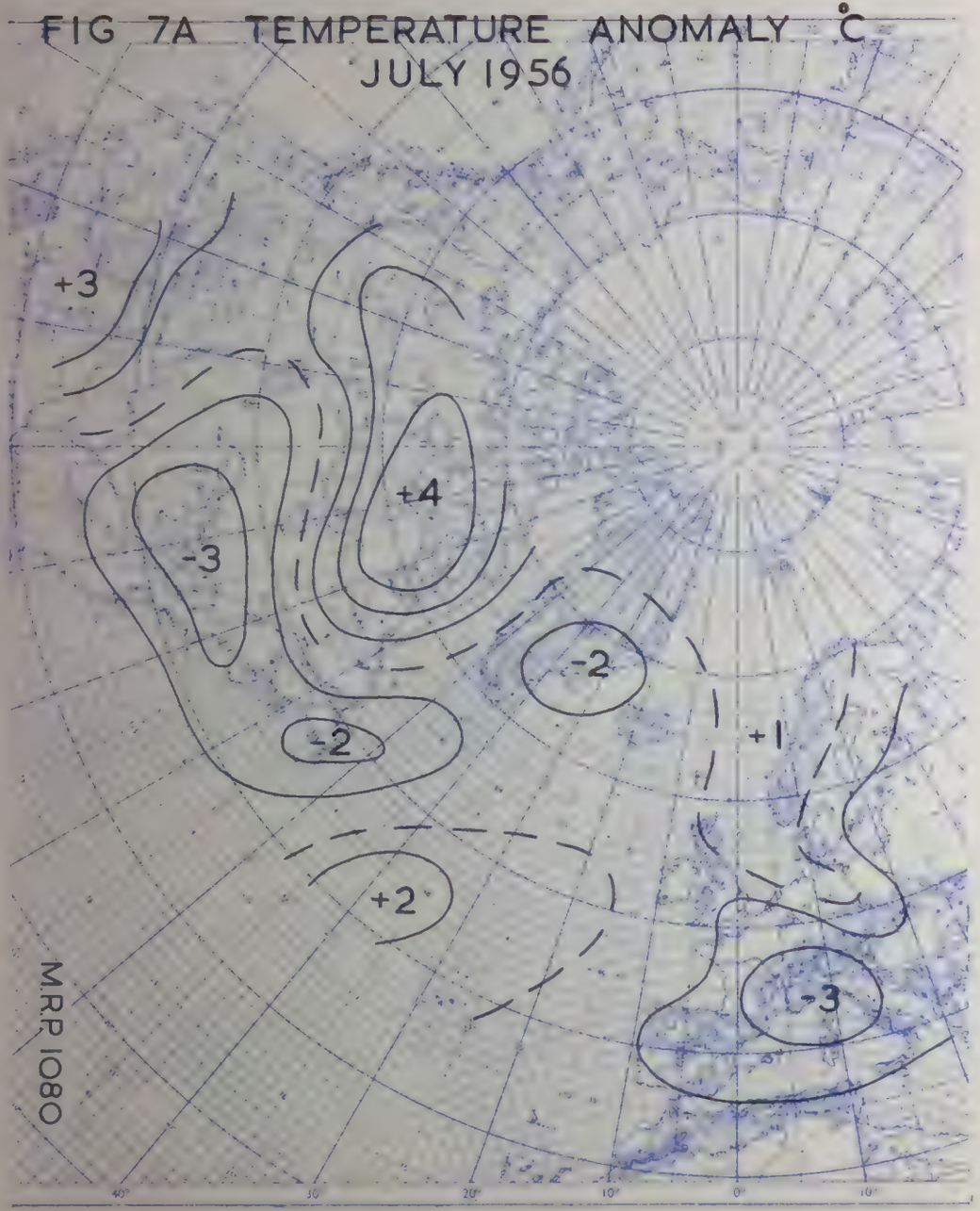

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FIG 7B THICKNESS ANOMALY M.°C
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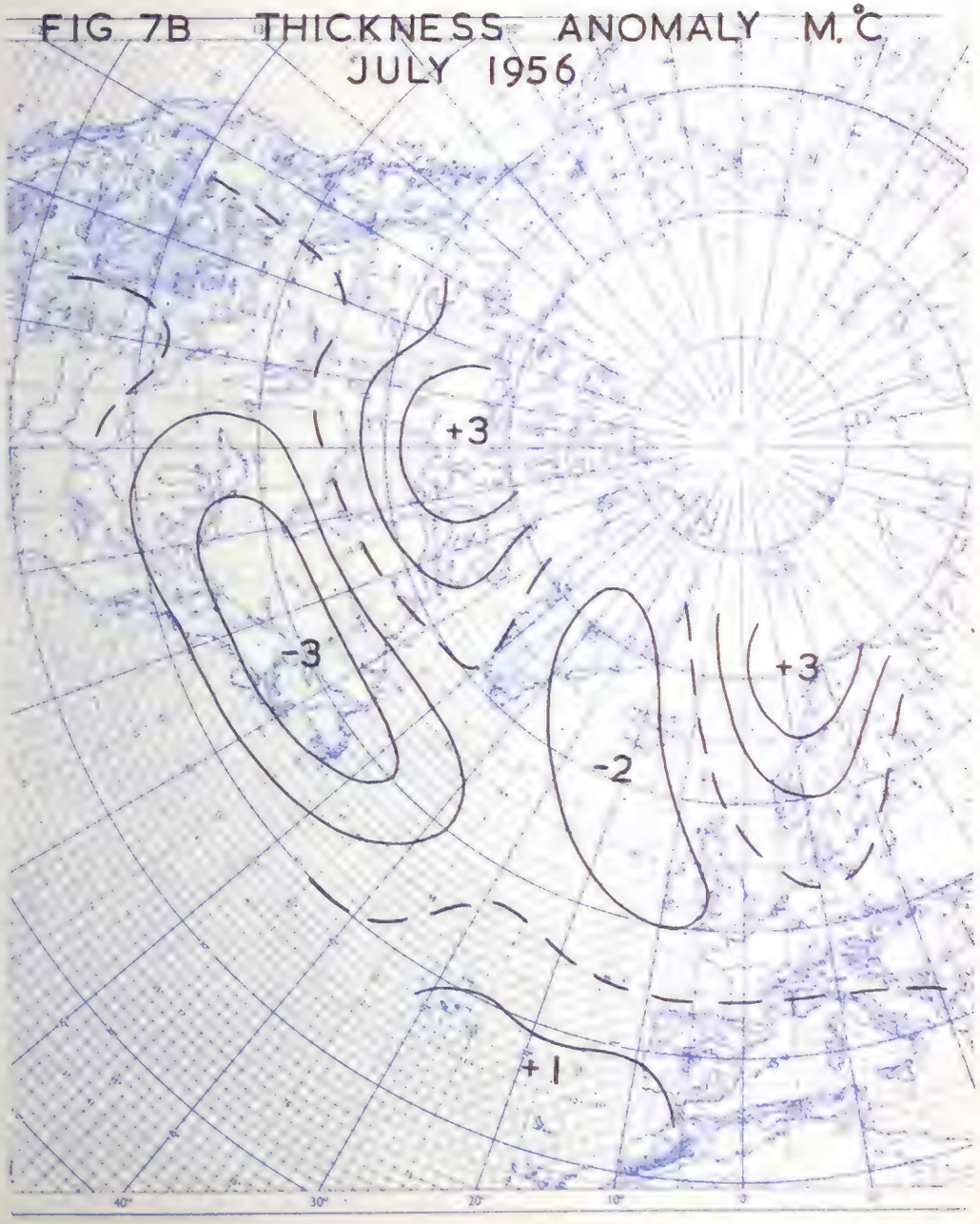

FIG 8A TEMPERATURE ANOMALY °C
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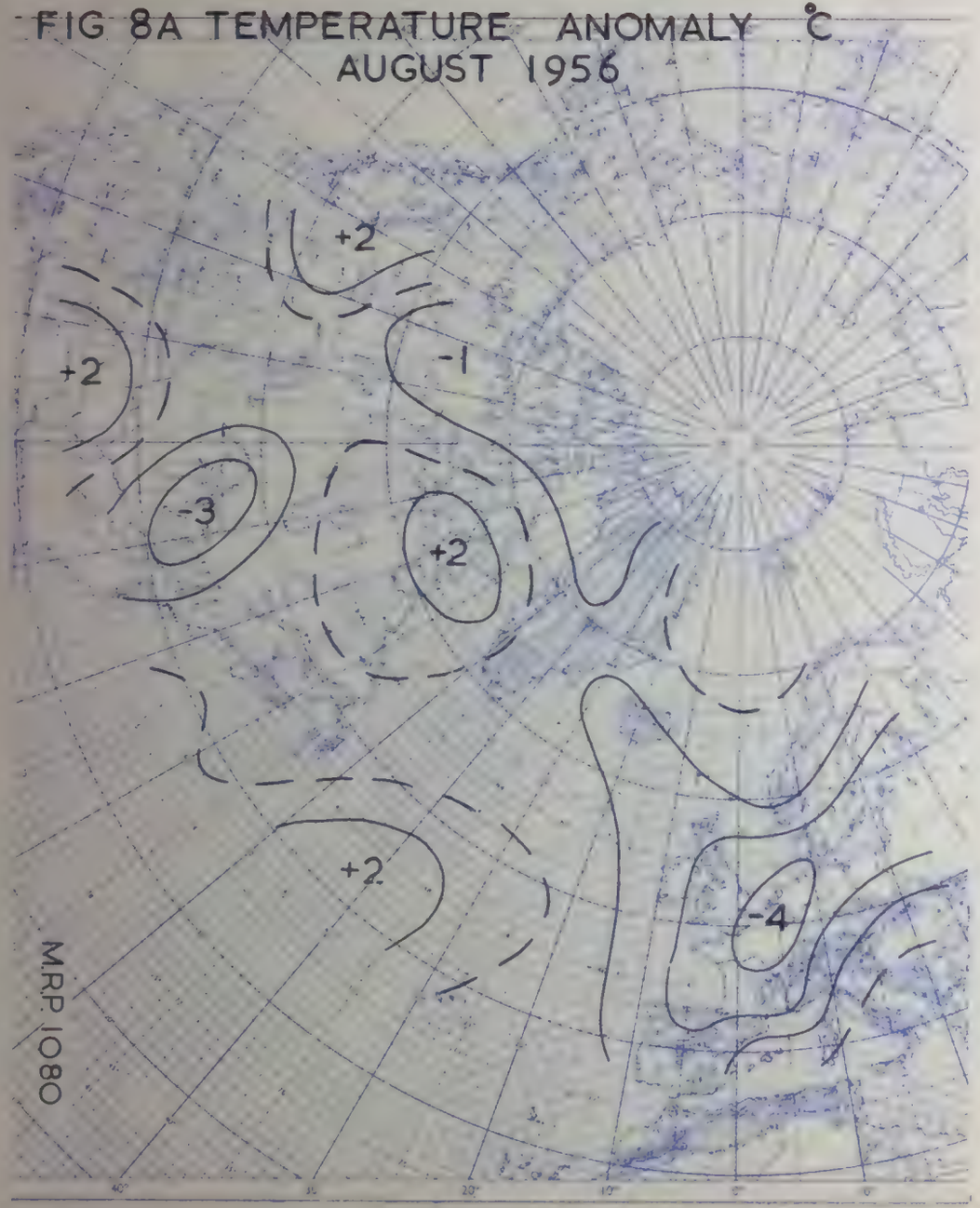

FIG 8B THICKNESS ANOMALY M. °C
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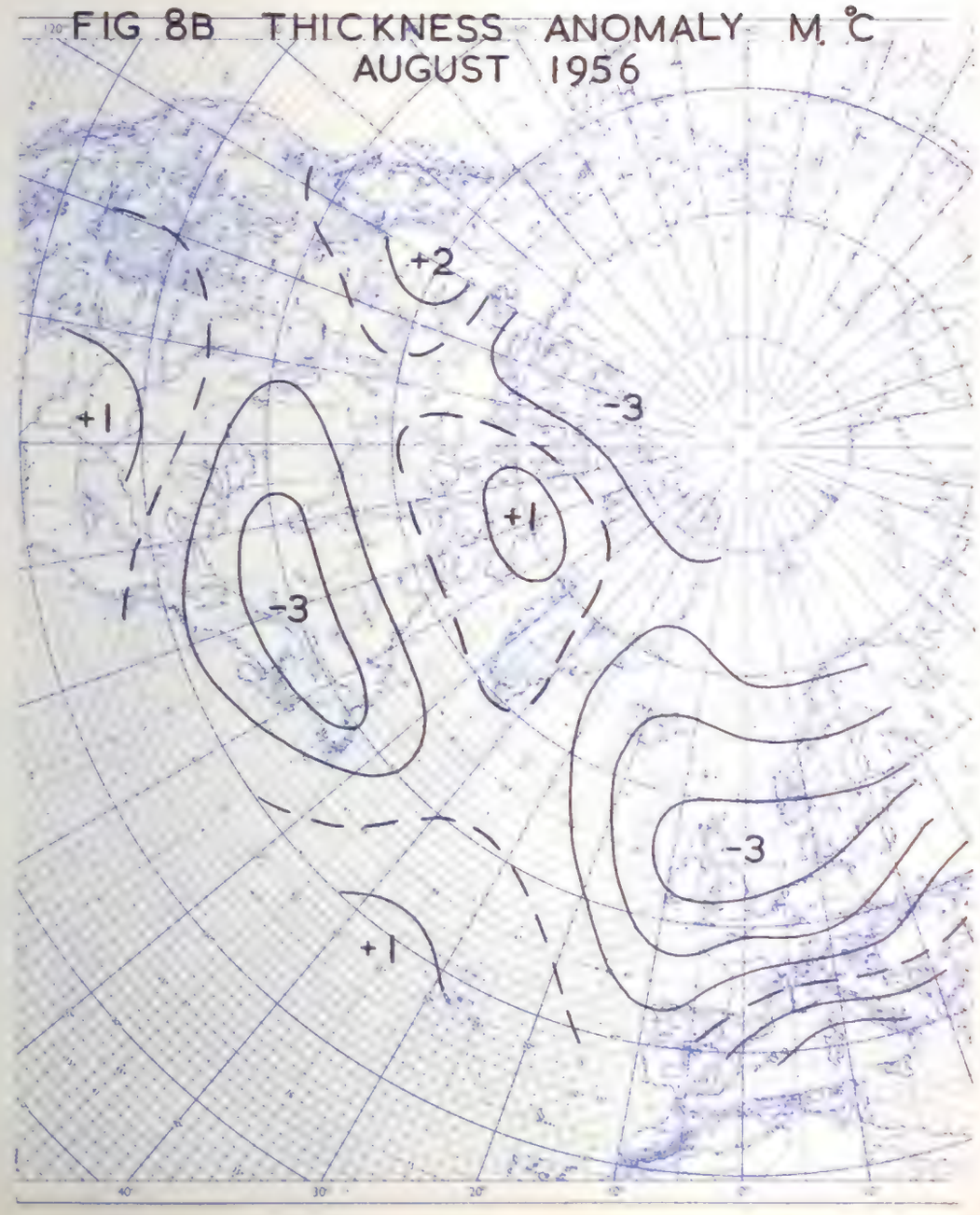

FIG 9A TEMPERATURE ANOMALY °C
SEPTEMBER 1956

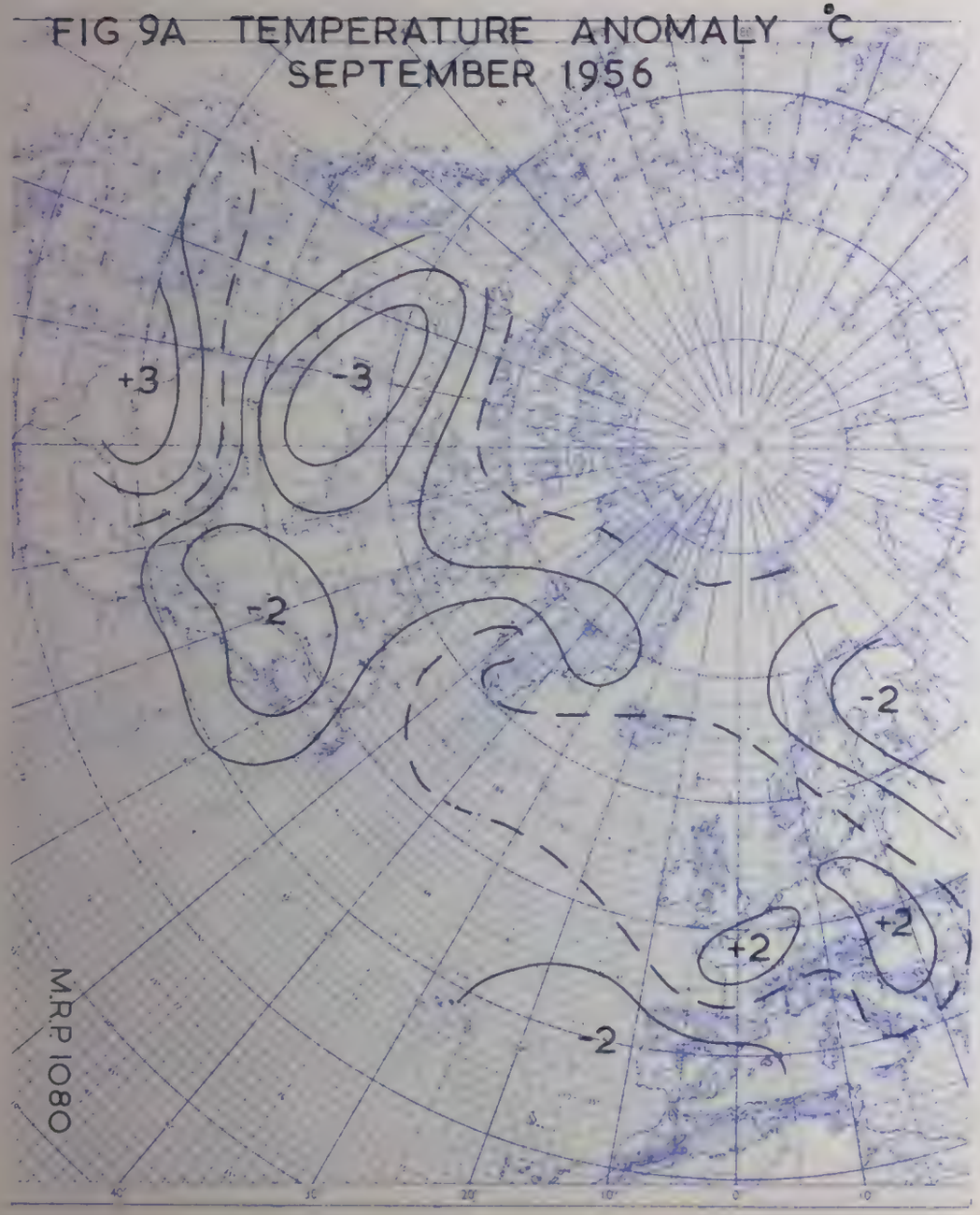

FIG 9B THICKNESS ANOMALY M. °C
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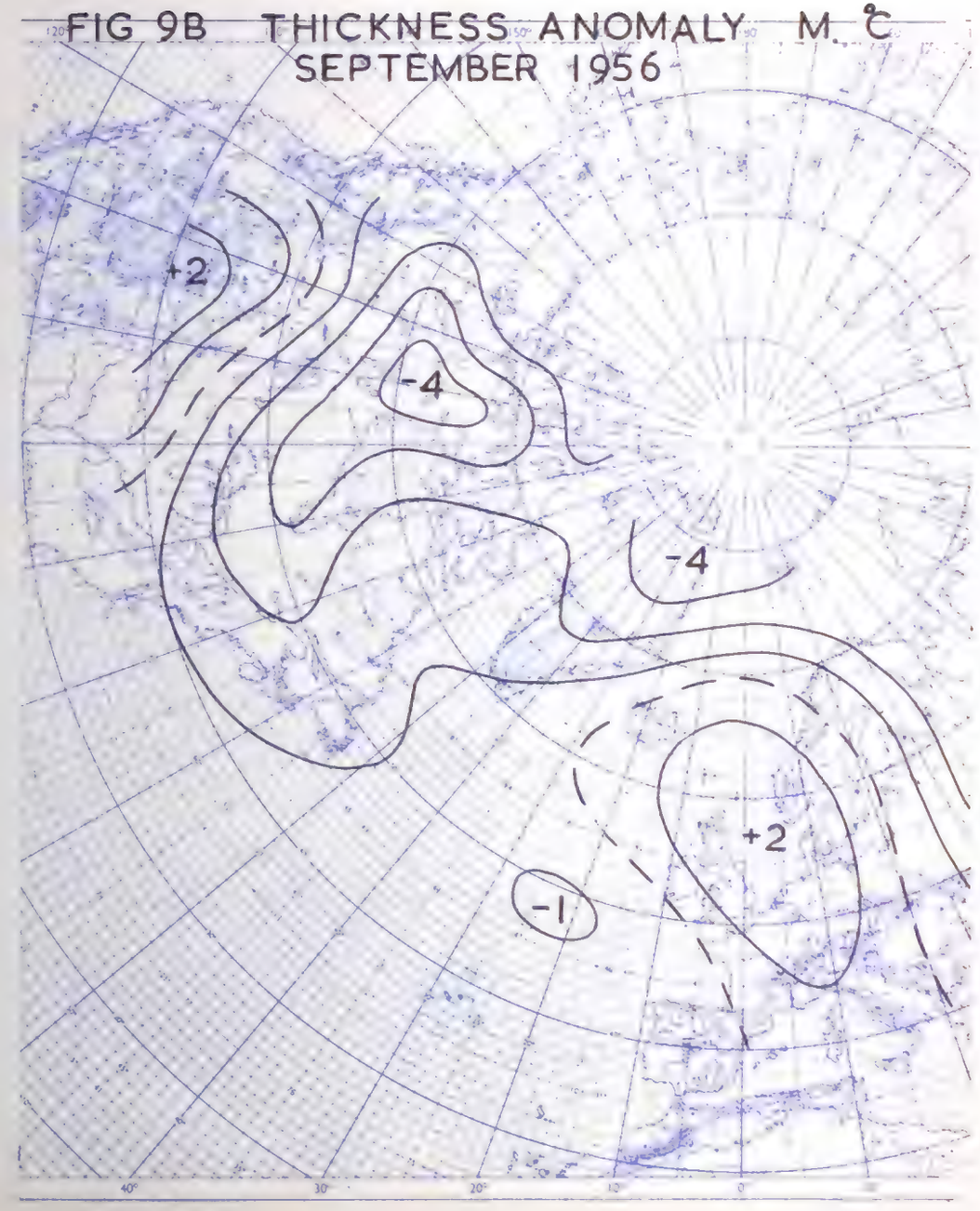

FIG 10A TEMPERATURE ANOMALY °C
OCTOBER 1956

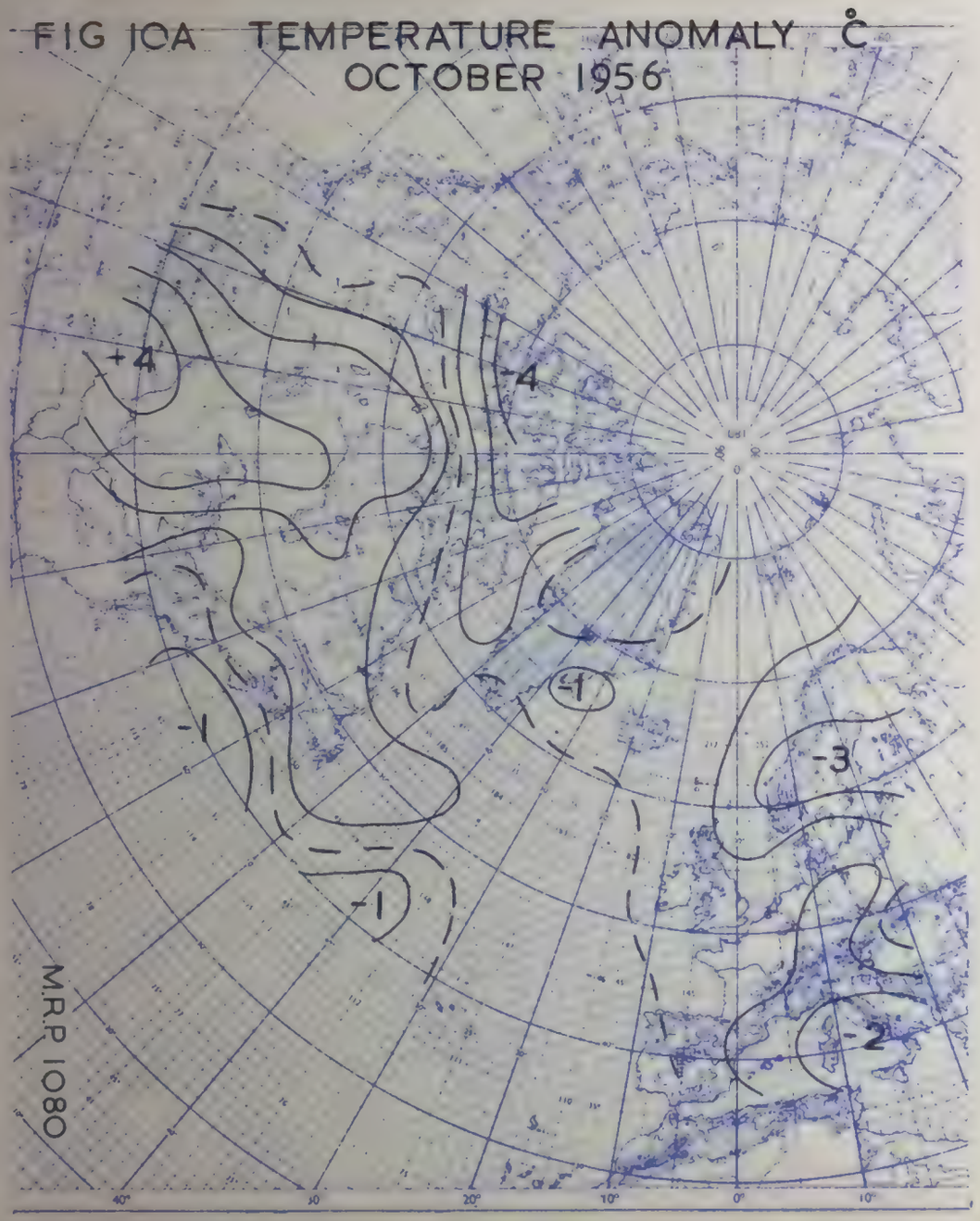

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FIG 10B THICKNESS ANOMALY M °C
OCTOBER 1956

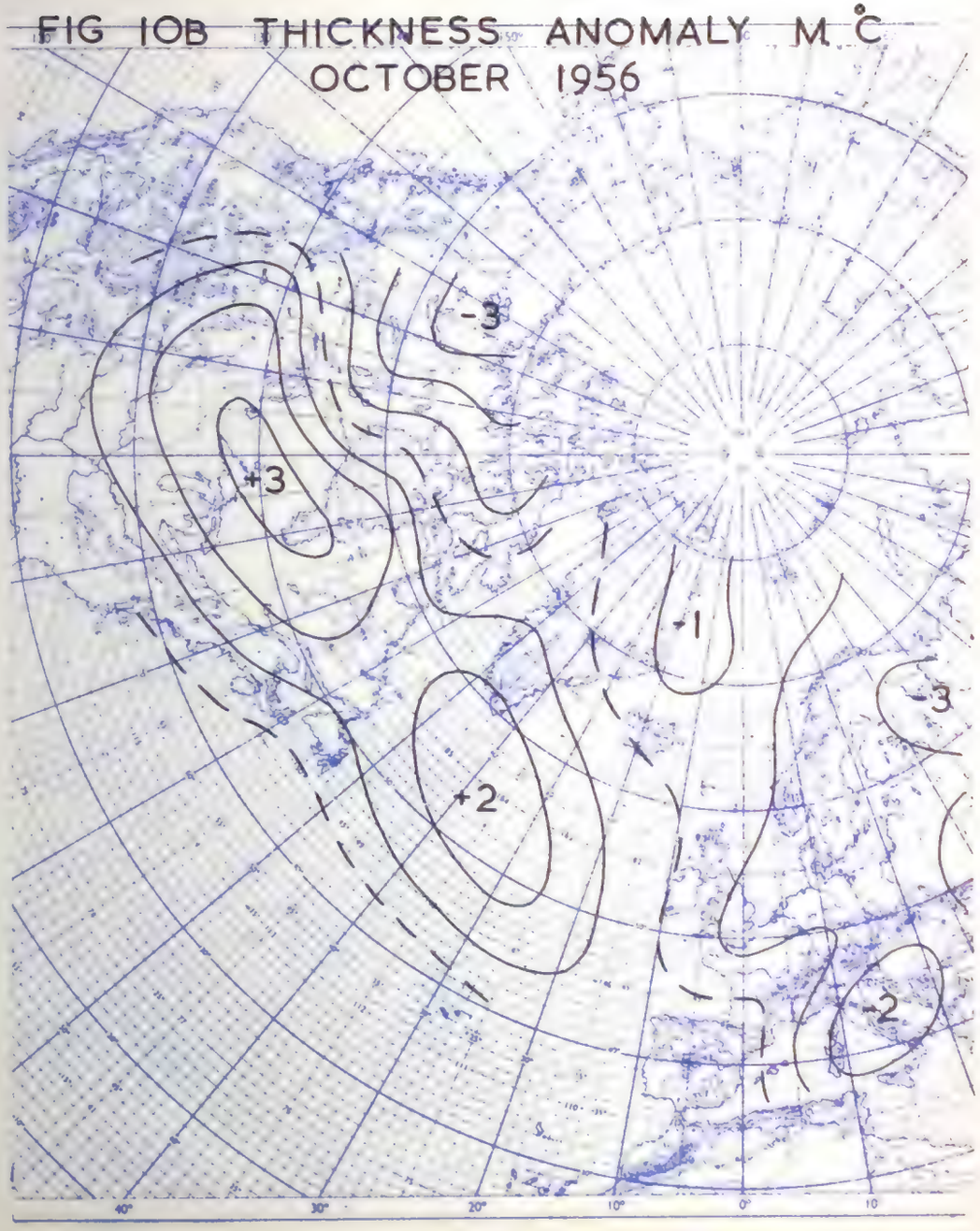

FIG IIA TEMPERATURE ANOMALY °C
NOVEMBER 1956

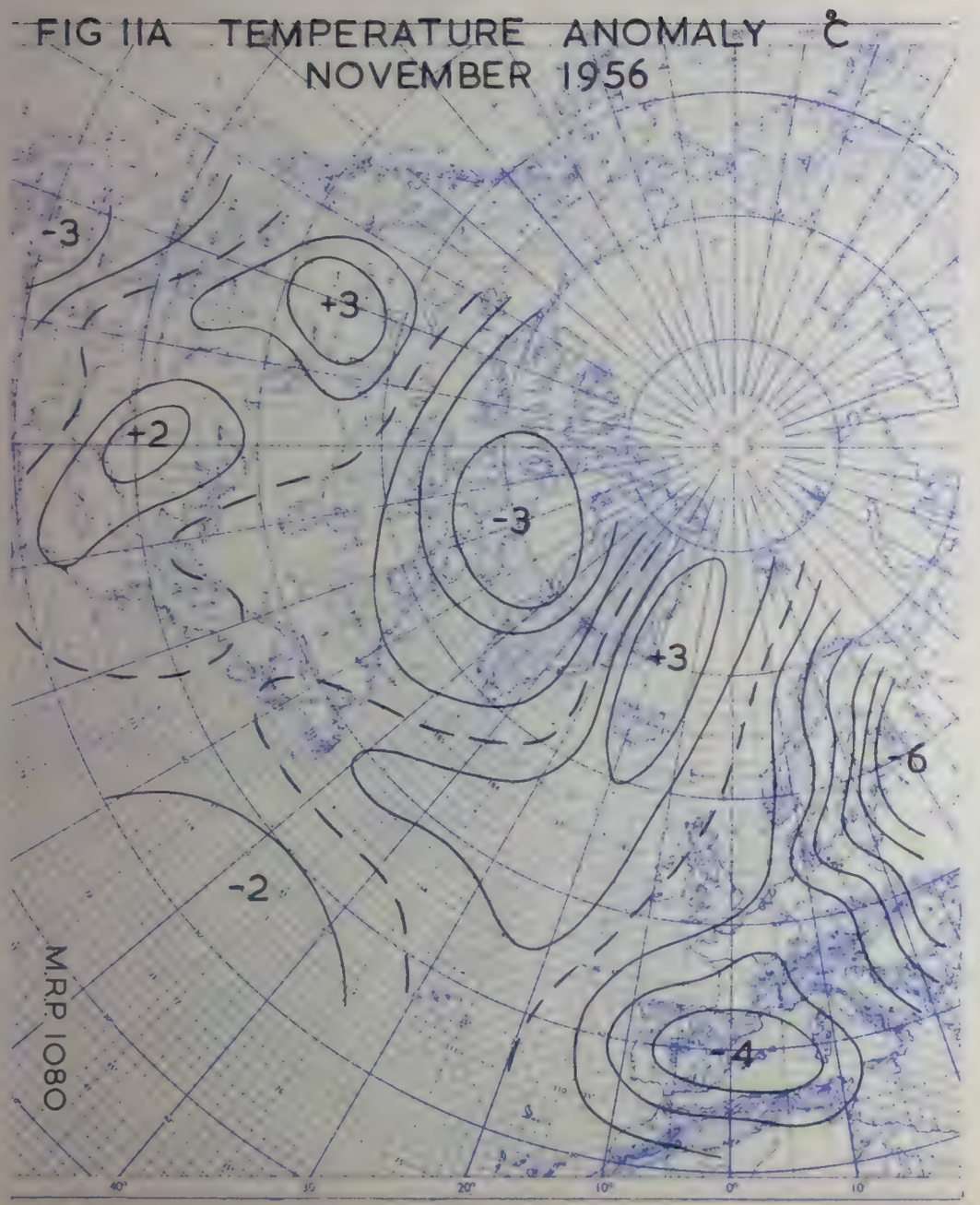

FIG IIB THICKNESS ANOMALY M °C
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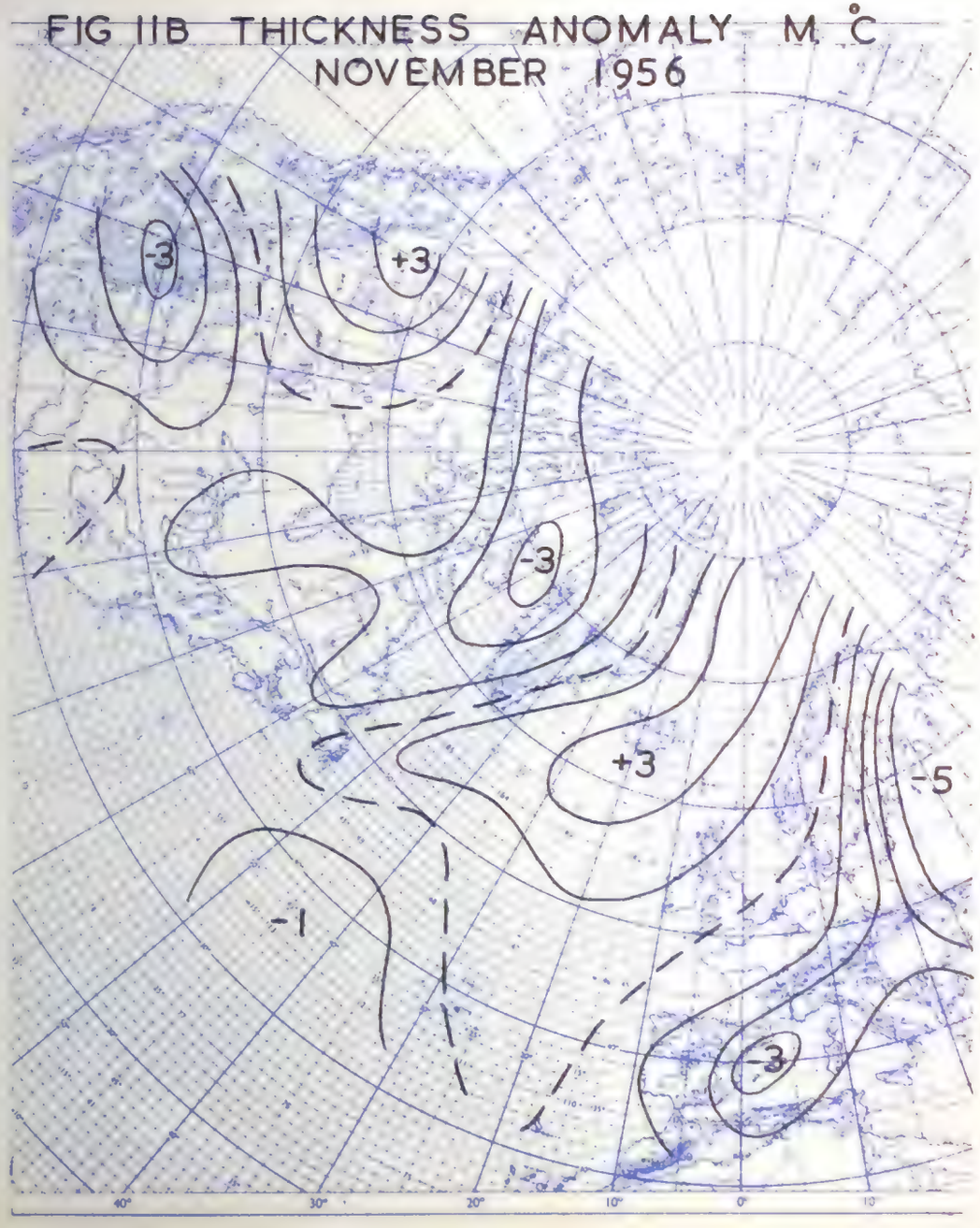

FIG 12A TEMPERATURE ANOMALY °C
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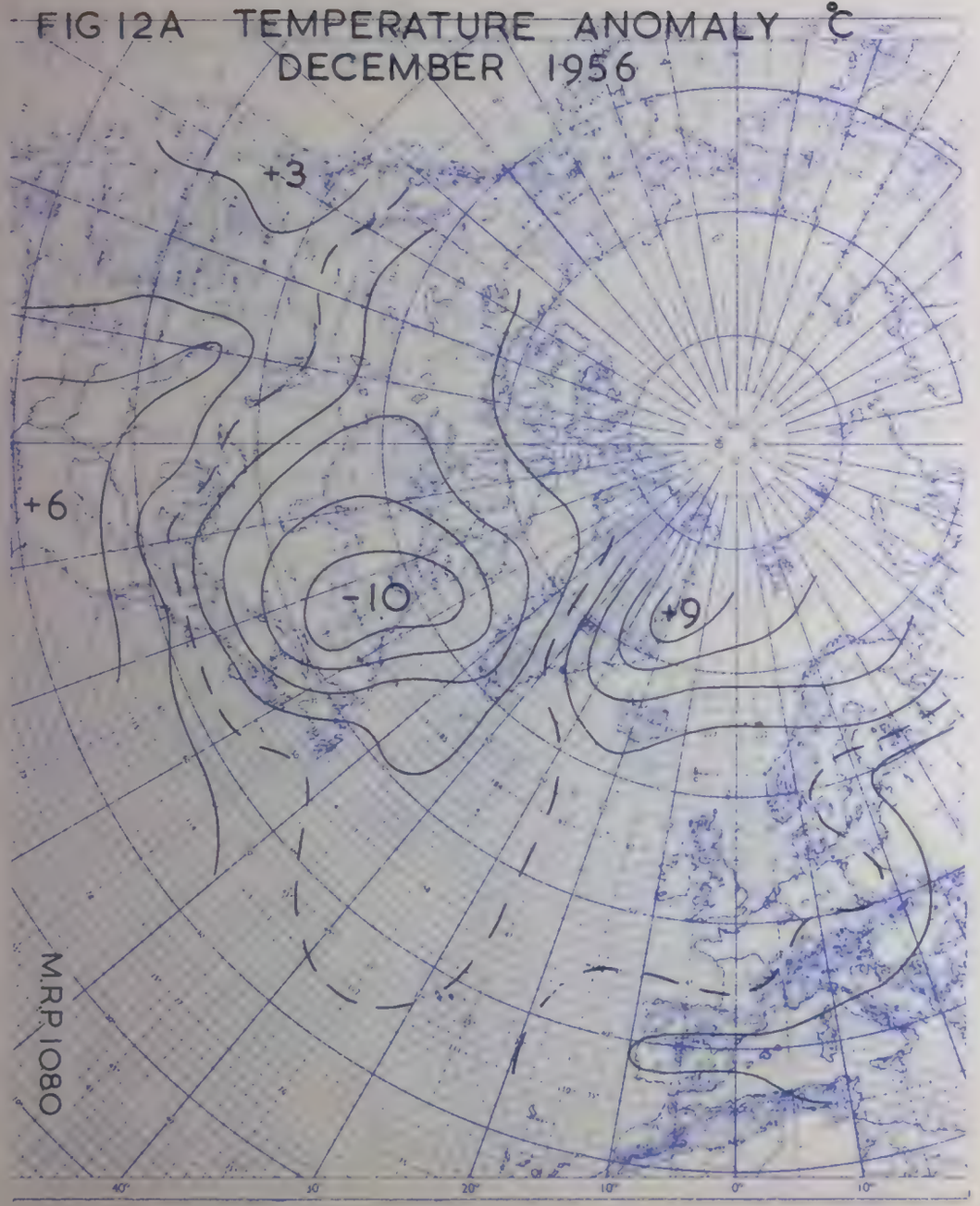
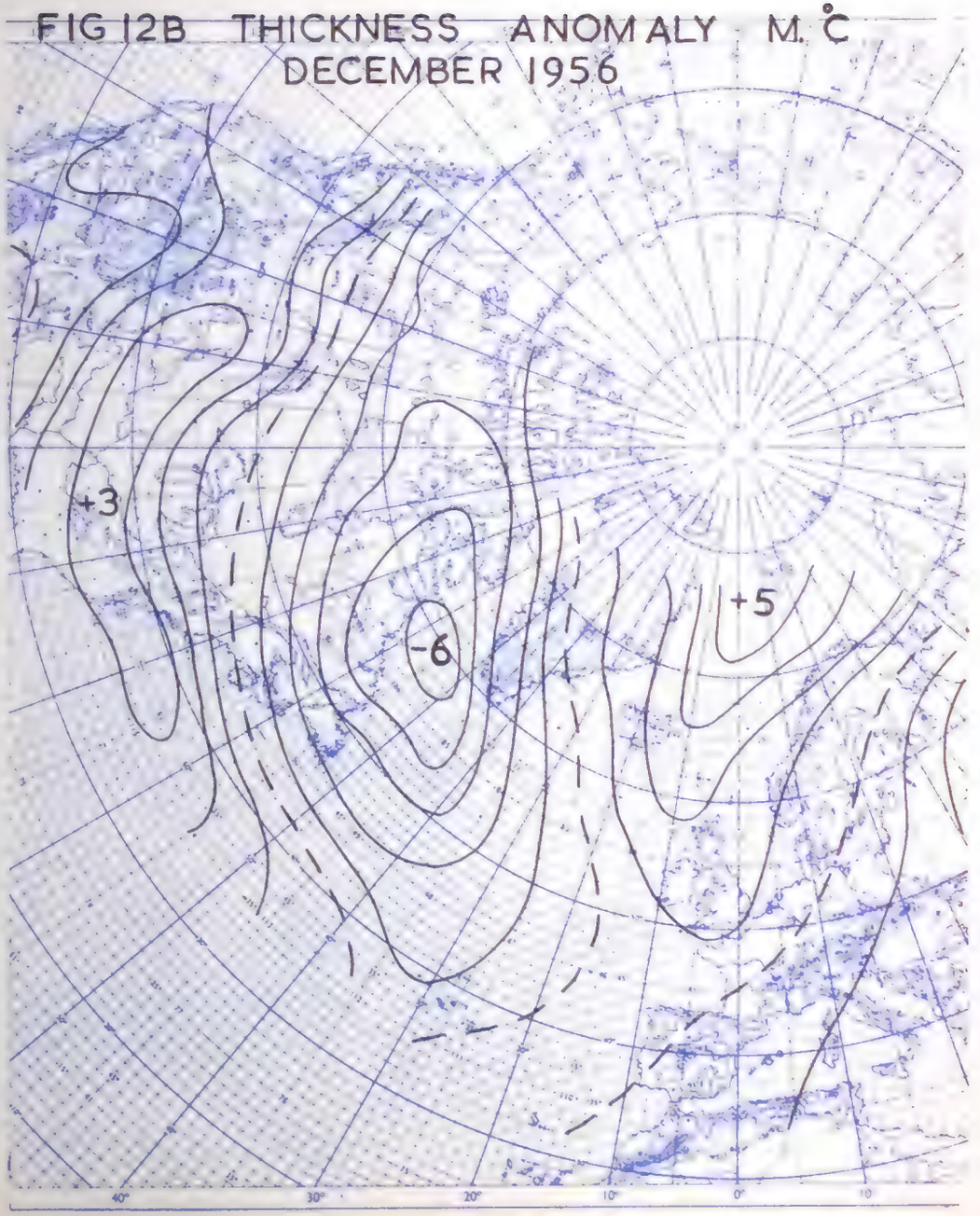
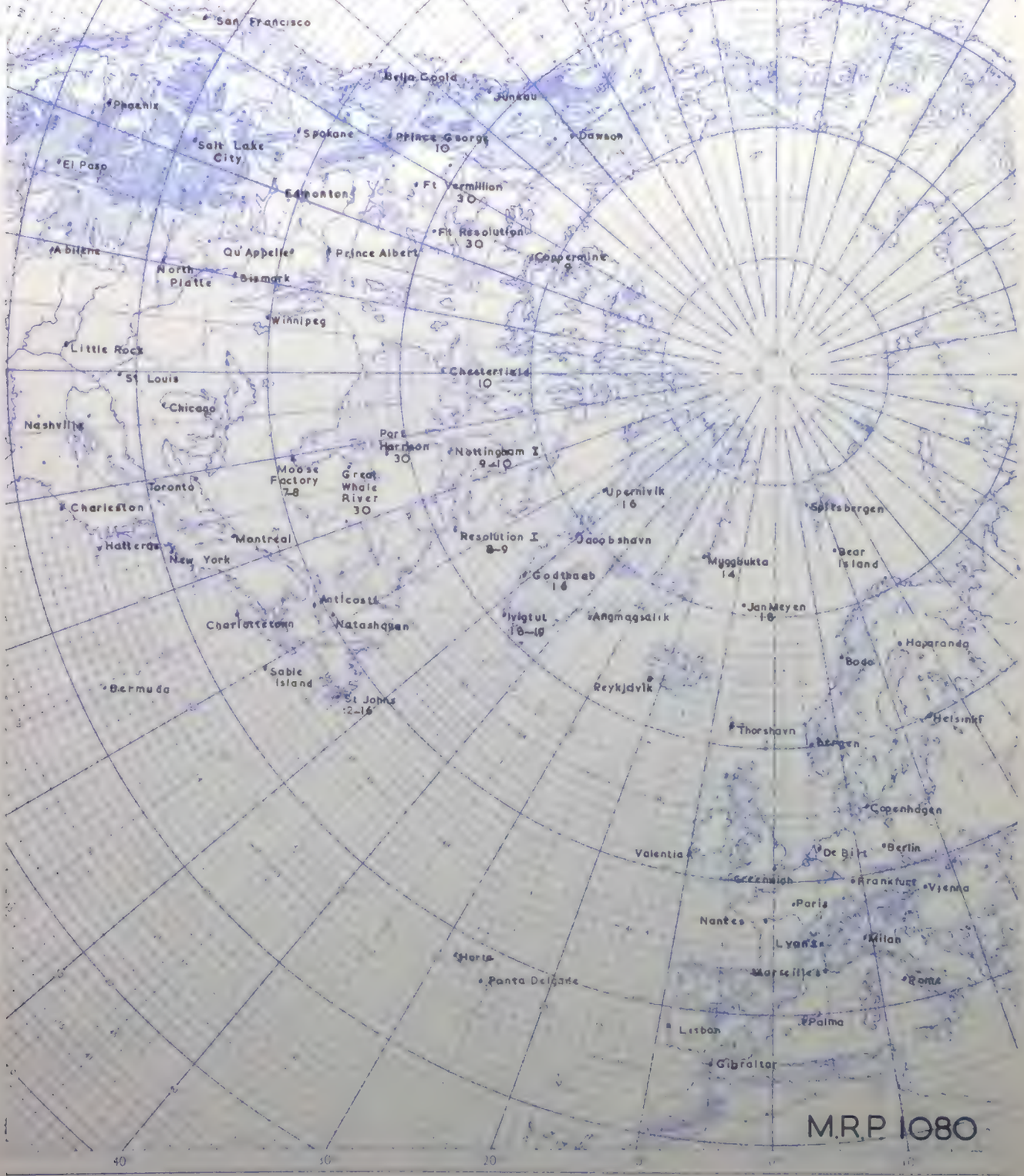


FIG 12B THICKNESS ANOMALY M. °C
DECEMBER 1956



KEY CHART: STATIONS USED FOR COMPARISON OF NORMALS



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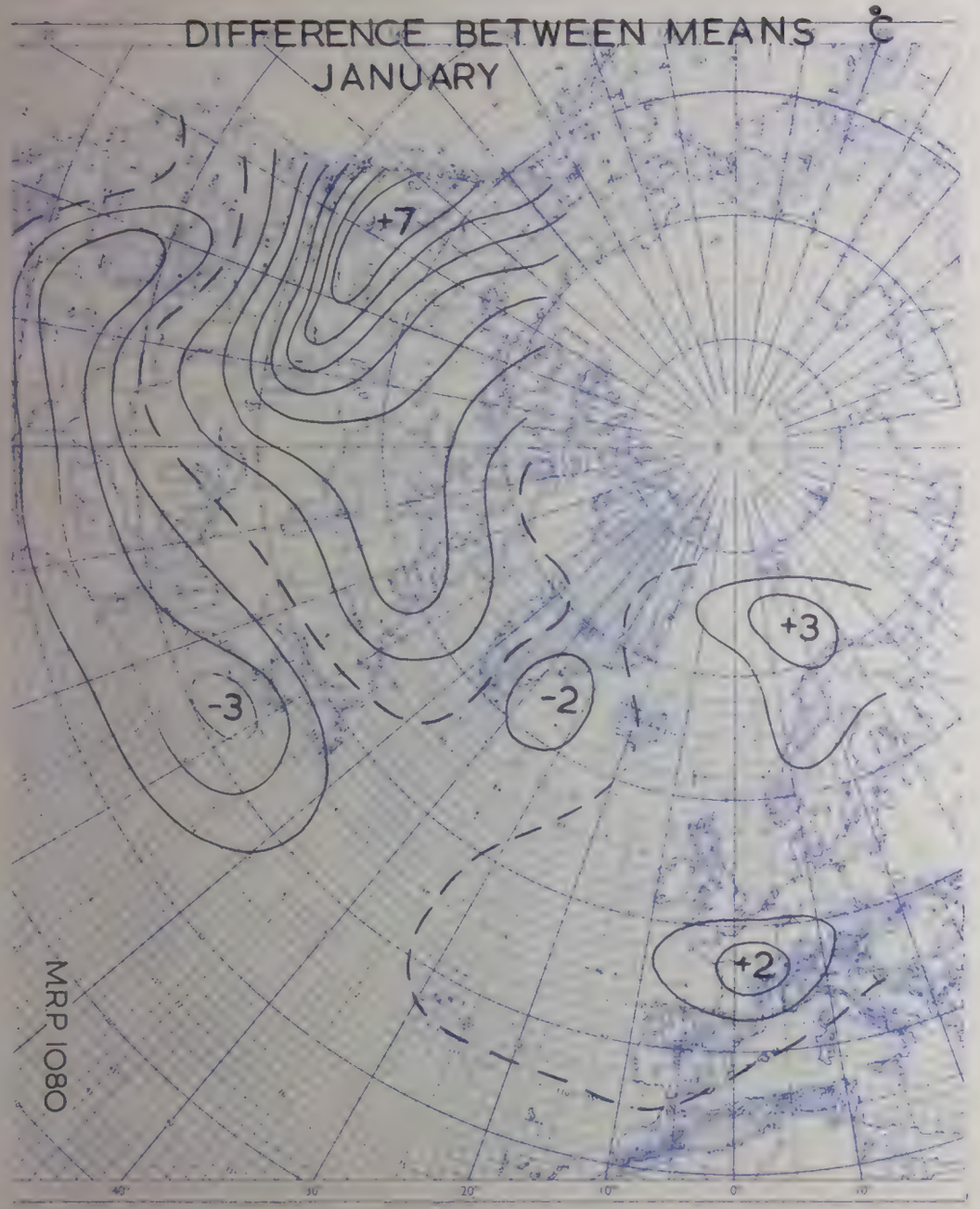
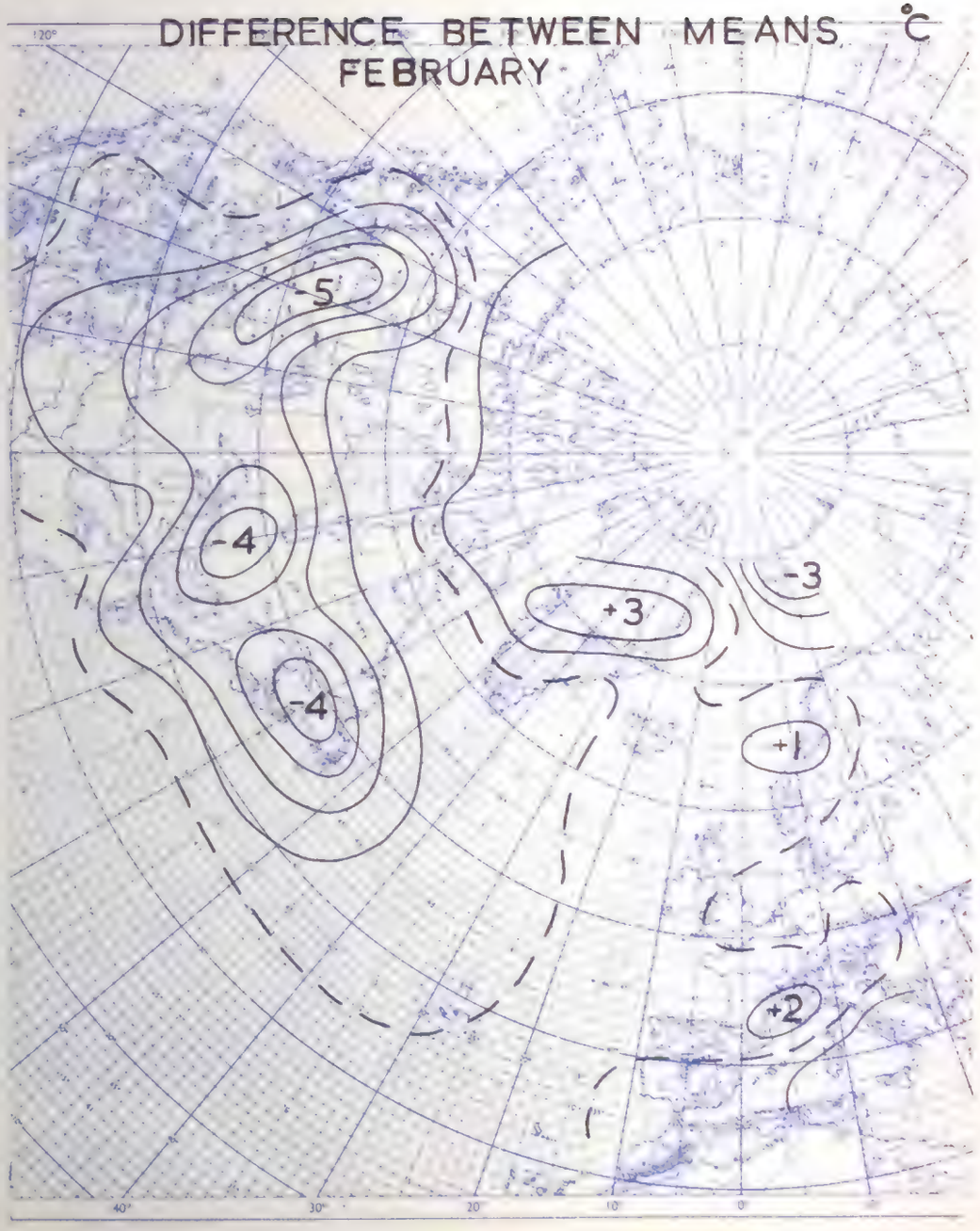
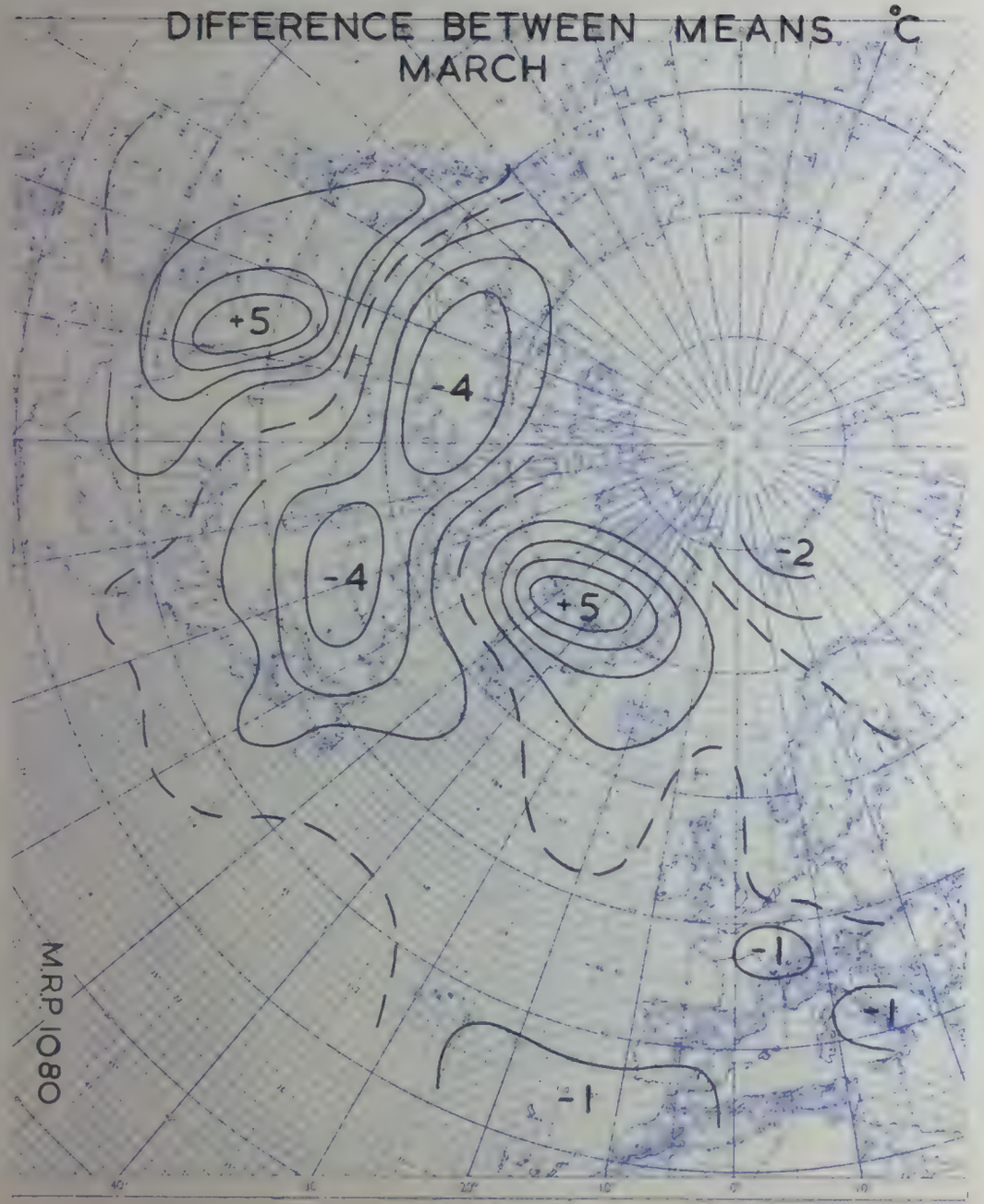
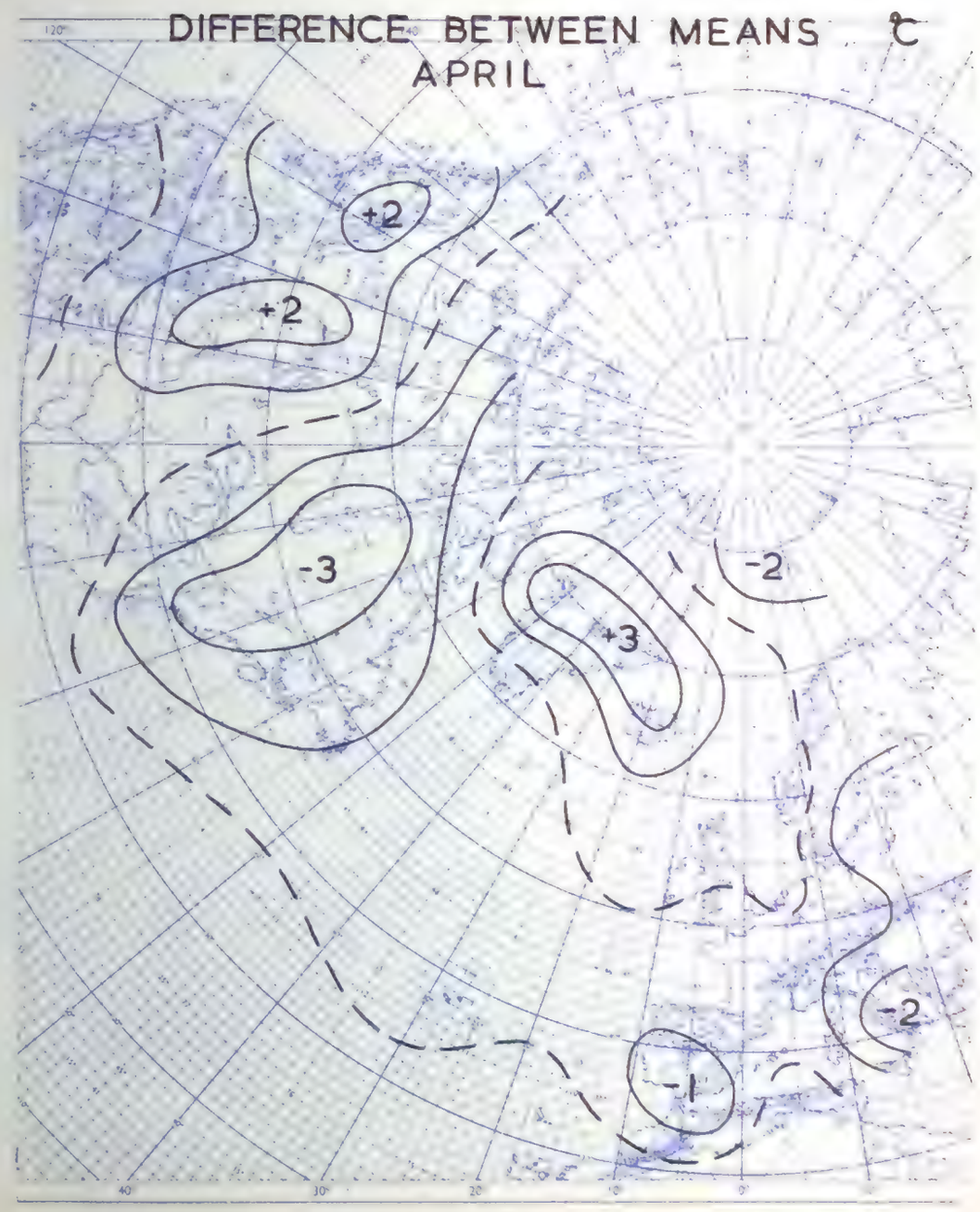
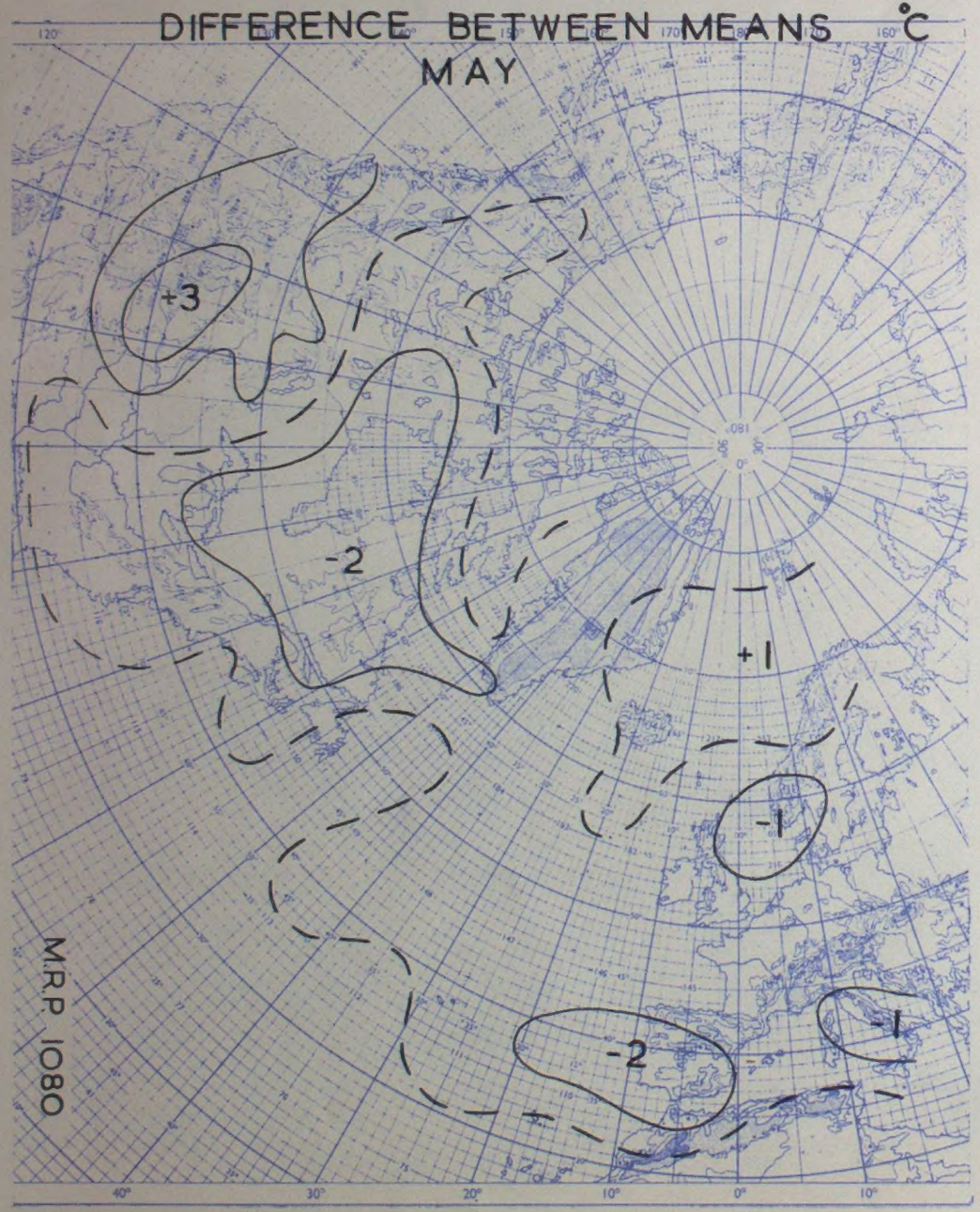
APPENDIX

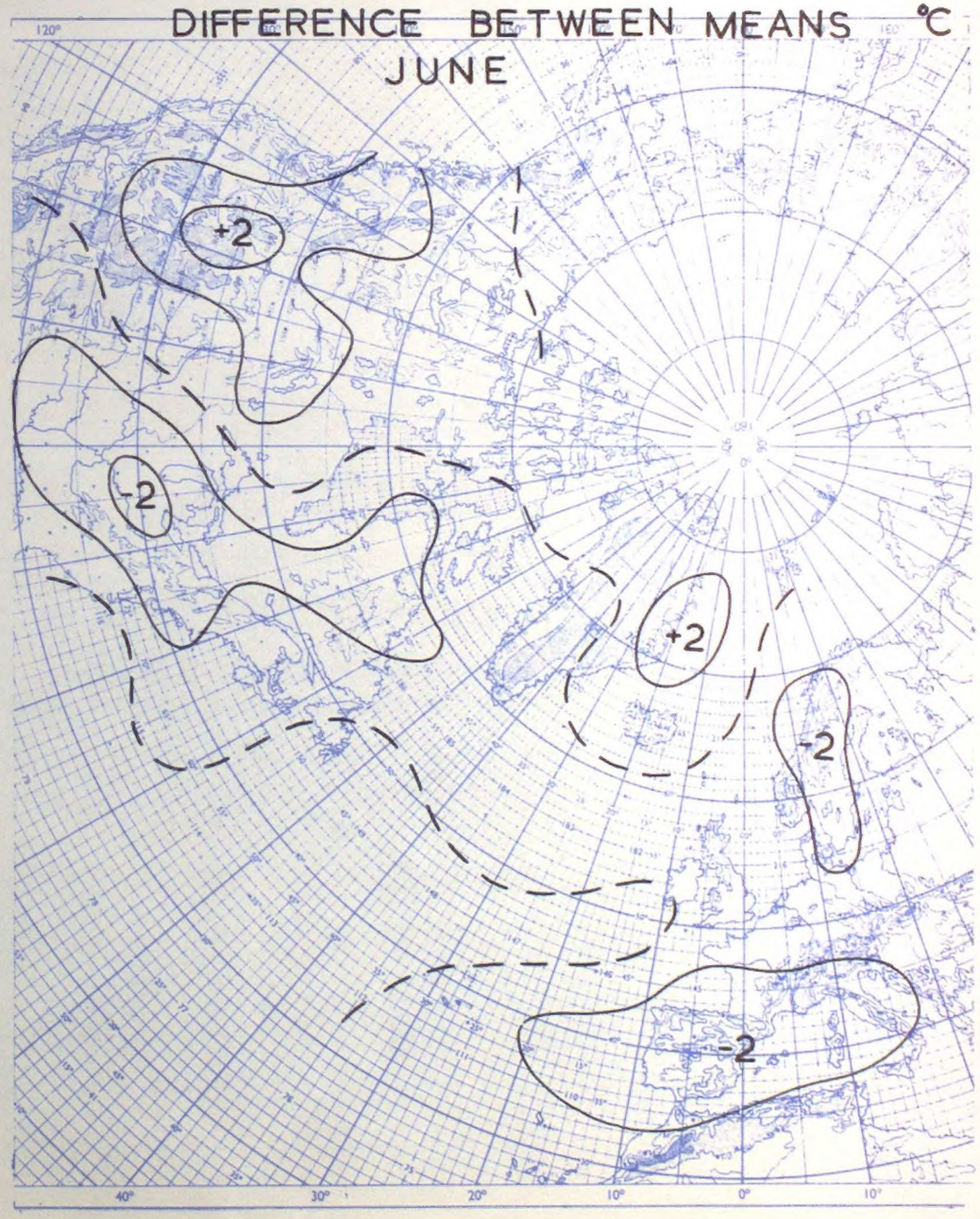

DIFFERENCE BETWEEN MEANS °C
JANUARY
+7
-3
-2
+3
+2
MRP 1080

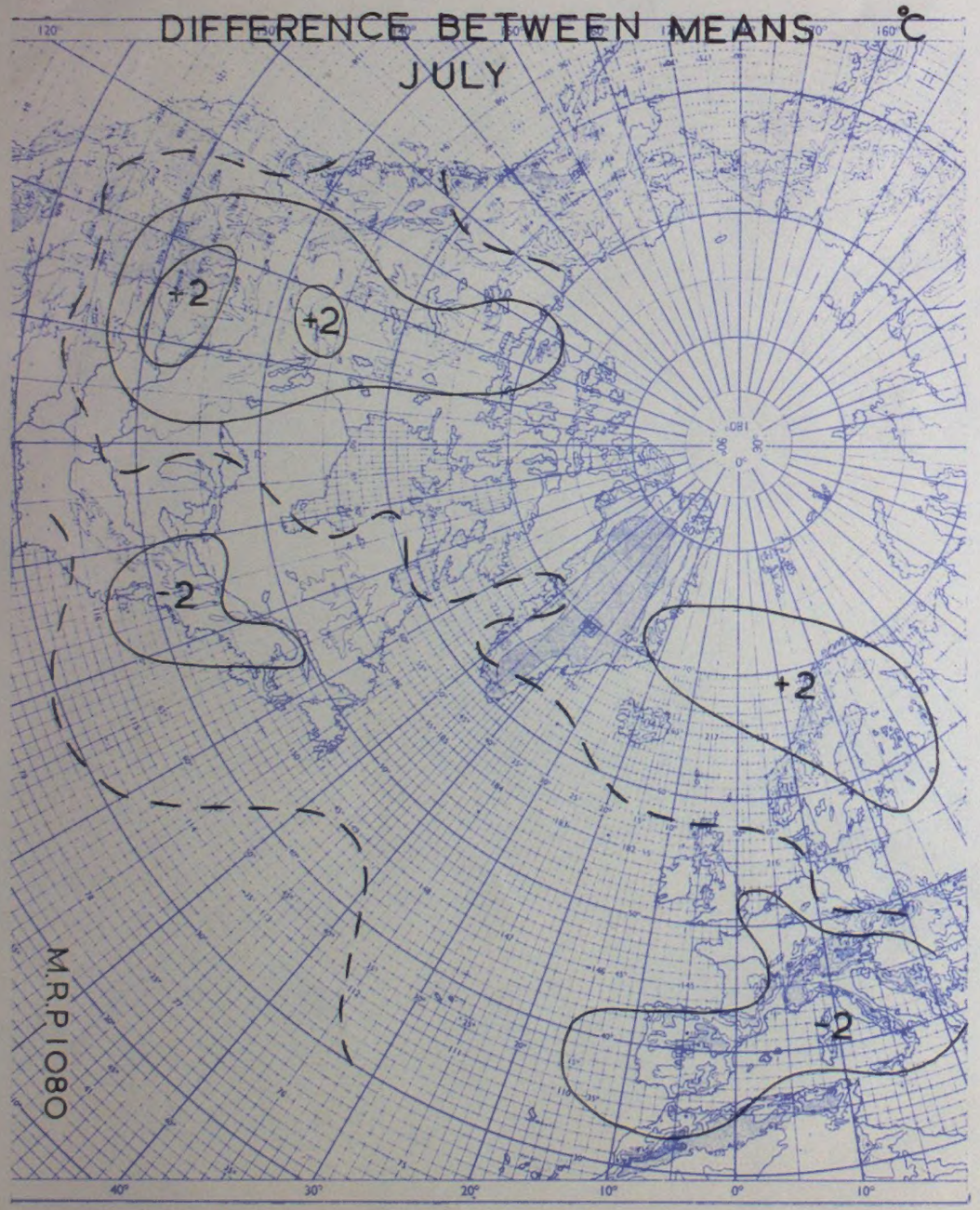

DIFFERENCE BETWEEN MEANS °C
FEBRUARY
-5
-4
-4
+3
-3
+1
+2

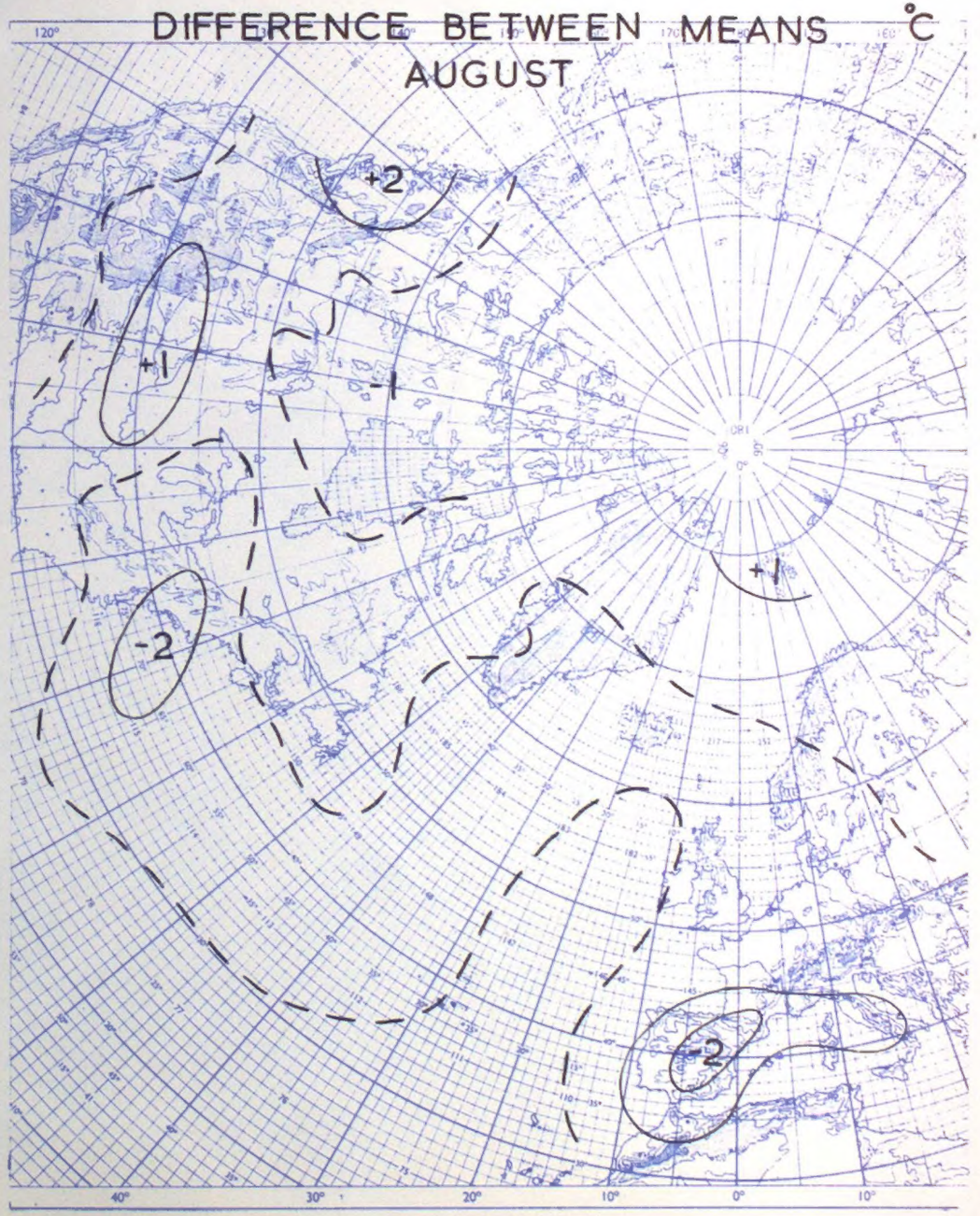

DIFFERENCE BETWEEN MEANS °C
MARCH
+5
-4
-4
+5
-2
-1
-1
-1
M.R.P. 1080

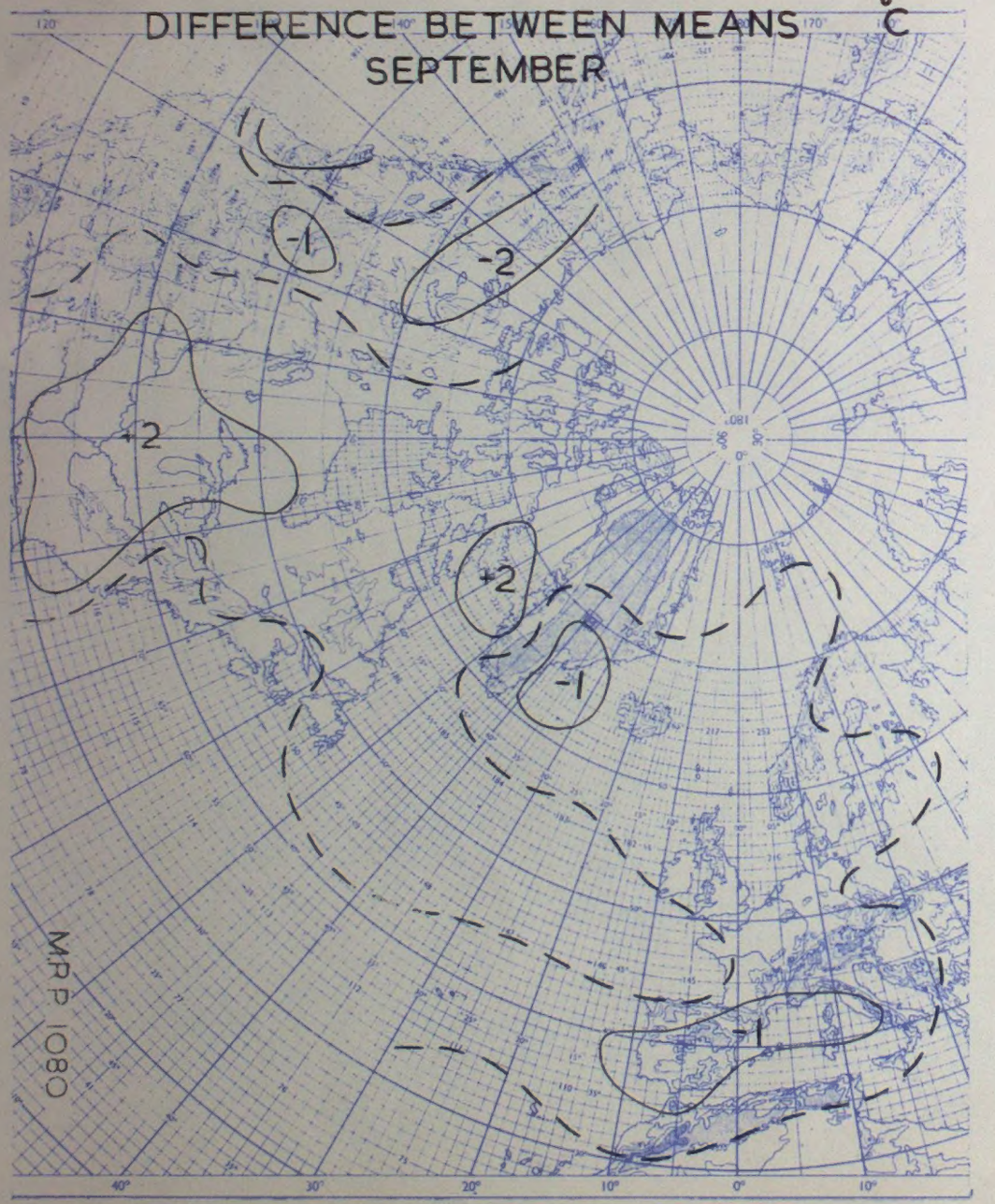

DIFFERENCE BETWEEN MEANS °C
APRIL
+2
+2
-3
-2
+3
-1
-2

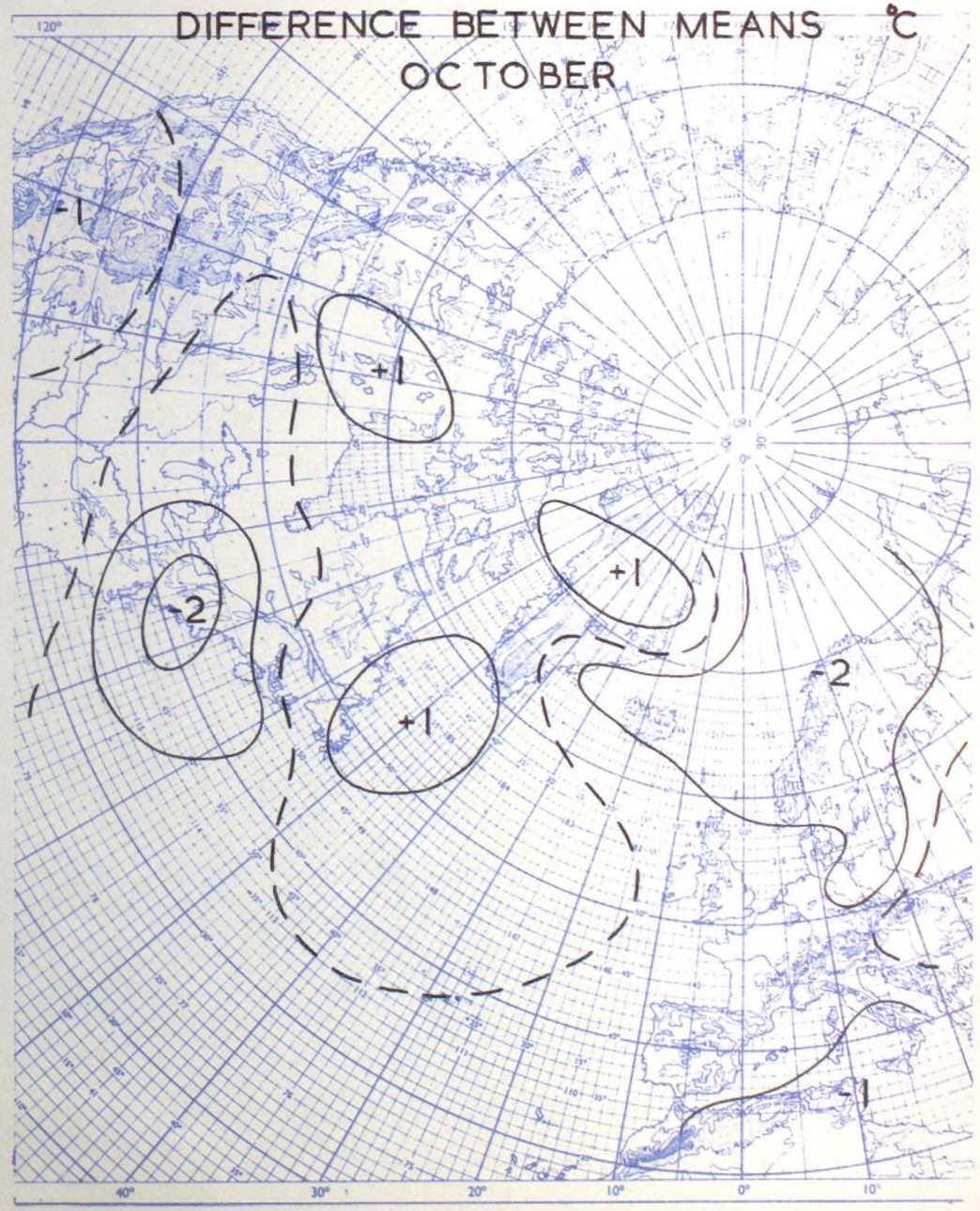

DIFFERENCE BETWEEN MEANS °C
MAY
+3
-2
+1
-1
-2
-1
M.R.P. 1080

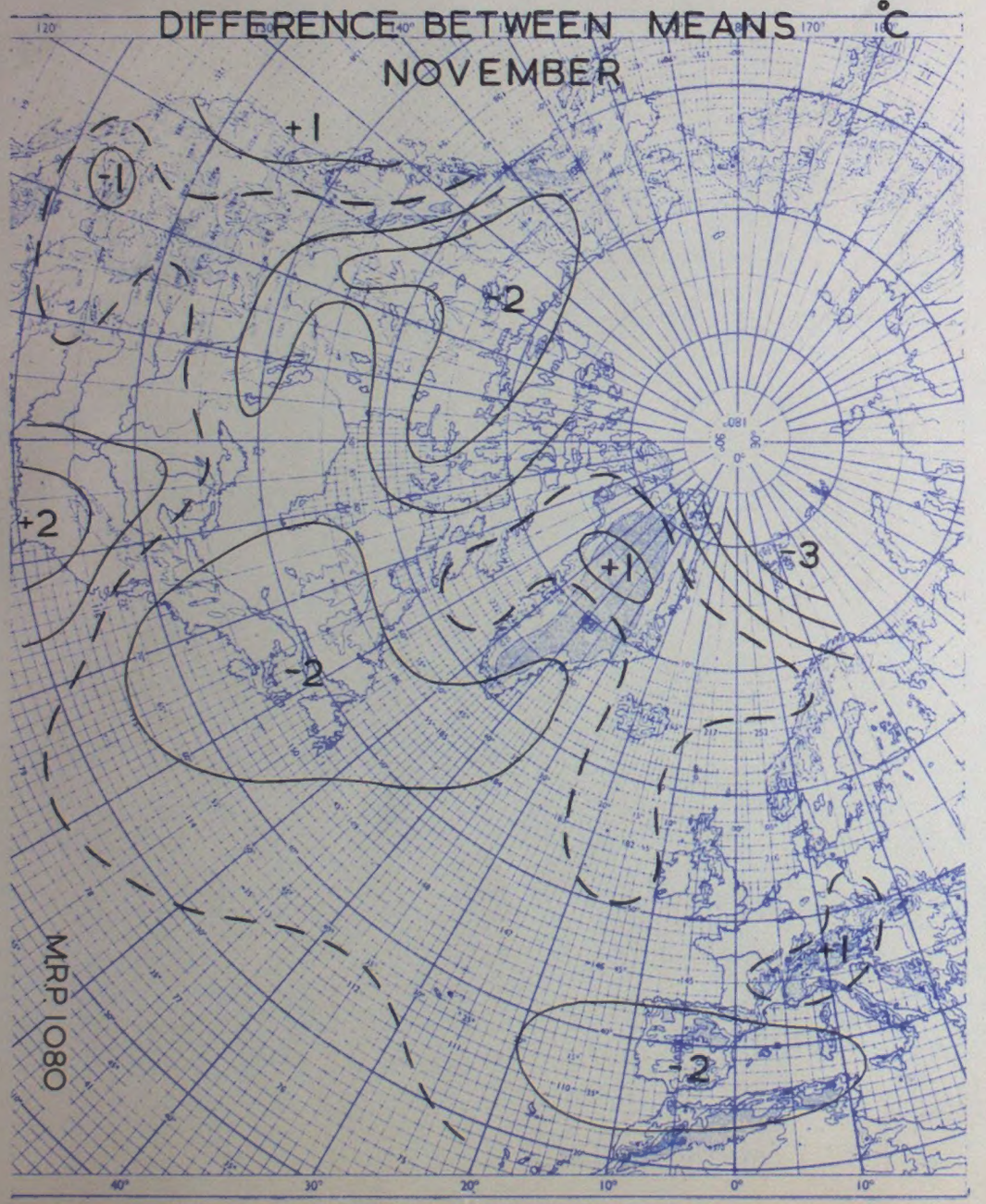

DIFFERENCE BETWEEN MEANS °C
JUNE
+2
-2
+2
-2
-2

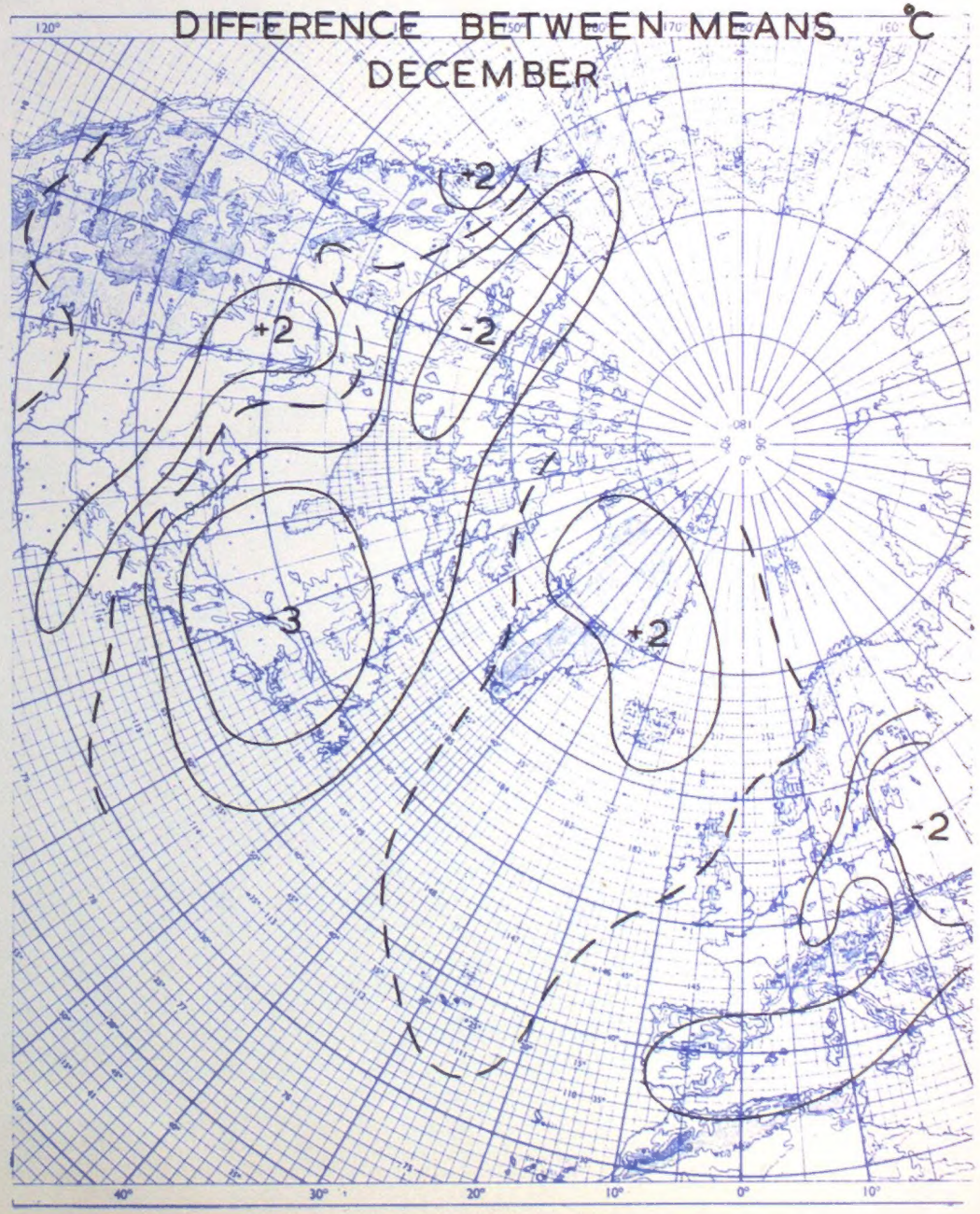

DIFFERENCE BETWEEN MEANS °C
JULY
+2
+2
-2
+2
-2
M.R.P.1080


DIFFERENCE BETWEEN MEANS °C
AUGUST
+2
+1
-1
-2
+1
-2


DIFFERENCE BETWEEN MEANS °C
SEPTEMBER
-1
-2
-2
+2
-1
-1
MRP 1080


DIFFERENCE BETWEEN MEANS °C
OCTOBER
-1
+1
-2
+1
+1
-2
-1


DIFFERENCE BETWEEN MEANS °C
NOVEMBER
+1
-1
+2
+2
-2
+1
-3
-2
+1
-2
M.R.P. 1080


DIFFERENCE BETWEEN MEANS °C
DECEMBER
+2
+2
-2
-3
+2
-2